

Date Palm propagation through tissue culture

P. N. Sivalingam*, Dhurendra Singh, Arjit Chaturvedi, Eshu Arora, Shiva Parihar and R. Bhargava

ICAR-Central Institute for Arid Horticulture, Beechwal, Bikaner, India

*Corresponding author: Email- pnsivalingam@gmail.com

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Abstract

Date palm is one of the important arid fruit crops, naturally propagated through offshoots and seeds. These methods of propagation are not sufficient to meet the demand of genetically uniform large scale plantation of female date palm plants. This demand has been realized through tissue culture methods; embryogenesis and organogenesis. Initially somatic embryogenesis (SE) protocols have been developed for several cultivars of date palm in different countries for its large scale multiplication and planted in the field. After noticing abnormalities in some of the date palm plants developed through SE due to somaclonal variations, organogenesis method has been developed though it has low multiplication rate. Now-a-days date palm is commercially produced by organogenesis method in Morocco, UAE and Saudi Arabia. Research focus has also been given on identification of somaclonal variations in date palm plants produced by SE method by molecular markers, increasing multiplication rate in organogenesis method by modifying cultural conditions, automation of protocols, identification of exact cells involving in embryo formation and their mechanisms, etc. In India, recently SE protocol developed by public sector for commercial use and several public and private sectors involved in production of date palm plants by tissue culture approach. However many challenges ahead still needs to be resolved are; precise identification of somaclonal variants in *in vitro*, increasing multiplication rate in organogenesis, reducing duration in juvenile phase for callus induction in SE and shoot bud formation in organogenesis, developing genotype independent tissue culture protocols.

Key words: Date palm, embryogenesis, organogenesis, propagation

Introduction

Date palm (*Phoenix dactylifera* L., family- *Arecaceae*) is a dioecious, tall ever green, cross-pollinated, perennial monocotyledonous and most important fruit crop of the arid regions of the world (Taha *et al.*, 2001). This can successfully tolerate adverse environmental conditions such as drought, salinity and high temperature which are the peculiar conditions of desert (Bekheet *et al.*, 2008). It has domesticated and thought to have originated in the Southern Near East (Zohar and Spiegel Roy, 1975). It is distributed in Middle East and Arab countries, North Africa and South Sahel, areas of East and South Africa and Asia even in parts of Europe and USA. Total world production of dates was 7.55 million tonnes (MT) from 1.1 million hectare (Mha) land (~100 million date palm trees) (FAO, 2013) and Egypt alone produced 1.47 MT during 2012. In India date palm cultivated in approximately 0.0168 Mha with the production of 0.125 MT.

Date palm is naturally propagated through sexually by seeds and asexually by suckers. Being a dioecious crop, the male and female flowers are in separate tree allowing for cross pollination which creates heterogeneity among the progenies. Moreover, the seed propagated plants are approximately 50 per cent are male plants which produce no fruits. More over few male trees are enough to pollinate

female trees in the field. Another disadvantage is the growth and multiplication of seed propagated seedlings is slow and takes 8-10 years or more to yield fruit. Traditionally, the propagation of date palm is achieved by using offshoots that are produced from axillary buds. These offshoots are true to type as they are asexually propagated and it comes to the fruiting 2-3 years earlier than seed propagated date palm trees. The disadvantage of using offshoot propagations are, (i) offshoots are produced only early stage of life cycle of tree (10-15 years) depending upon the genotypes (ii) limited in number per tree (maximum 15-20). The use of tissue culture is the most suitable approach for large scale plant multiplication in vegetatively propagated crops as it offers several advantages like, pest and disease free seedlings, large scale multiplication, genetically uniform plants of same sex, easy and fast exchange of planting material and germplasm exchange and economically reliable if produced in large scale (Zaid and Arias-Jimenez, 2002). Therefore, large scale production of female planting material of elite genotypes of date palm depends on tissue culture.

Micropropagation through organogenesis and embryogenesis methods has been successfully applied in date palm. Until now, the micropropagation of date palm has been limited success, World market need about 2 million date palms per year and approximately 25 research groups

are working world wide. Commercially, date palm plants produced through tissue culture by somatic embryogenesis in Israel, UAE, USA, UK and France and by organogenesis in Morocco, UAE and Saudi Arabia are produced through organogenesis. This review focuses on propagation of date palm plants through tissue culture in the World and in India by two methods (i) Organogenesis and (ii) Somatic embryogenesis.

Organogenesis

The regeneration of date palm plantlets through organogenesis was achieved in several countries outside India. This process involves initiation of meristematic shoot buds, shoot multiplication, shoot elongation and rooting, and acclimatization (Loutfi and El Hadrami, 2005; Zaid and Arias-Jimenez, 2002). The important and successful examples are also given in Table 1.

Initiation of meristematic shoot buds: Most of the meristematic shoot bud initiation from date palm cultures have been established from the internal face of young bases taken from offshoots (Beauchesne *et al.*, 1986; Beauchesne, 1988; Asemota and Eke, 2006; Khirellah and Badar, 2007; Abdul-Soad, 2006; Zaid and Tissert, 1983; Balal and El Deep, 1997). Other explants like petiole of female date palm (Costa and Aloufa, 2006) and male inflorescence (Bennasseur, 2007) are also used for shoot bud initiation. The meristematic bud induction usually takes 8-10 months under dark conditions in order to reduce tissue browning and phenolic compounds accumulation and to stimulate cell division (Loutfi and El Hadrami, 2005; Bennasseur, 2007; Abd El Bar and El Dawayati, 2014). The meristem induction from an explant depends on several factors and also by their interactions, which includes composition of culture medium, genotype of explants, stage and age of offshoots collected from mother plants etc. Procambial cells which are going to develop as vascular strand are has the ability to form proembryos not other cells or other differentiated tissues (Abd El Bar and El Dawayati, 2014).

Most of the researchers used MS media with different types and combinations of plant growth regulators and additives. Induction and formation of proembryo needs higher amount of cytokinin (Abd El Bar and El Dawayati, 2014). The growth hormones; auxins like NAA, NOA, IAA and IBA and cytokinins like BA, kinetin, and 2iP, occasionally TDZ were used in various combinations and concentrations. The explants responded better in combination of auxins and cytokinins, which are; (i) 0.01-1 mg/L of NAA+1 mg/L of NOA+ 1-4 mg/L of 2iP+1-5mg/L of BA (Asemota and Eke, 2006; Khirelladha and Badar, 2007) (ii) 4mg/L of IBA or IAA+0.5mg/L of NAA+ 1-5 mg/L BA or 2iP (Balal and El Deep, 1997; Mater, 1990), (iii) 5.4 μ M of NAA+4.9 μ M of IBA+5-27 μ M of NOA + 0.5 μ M 2iP (Poulain *et al.*, 1979) and (iv) 5.4 μ M of NAA +

5.7 μ M of IAA+5-27 μ M of NOA + 0.5-14.8 μ M 2iP (Beauchesne *et al.*, 1986) (v) 1 mg/L NAA + 3mg/L 2ip + 3 mg/L BA (Khan and Bi, 2012) (vi) 2mg/L 2ip + 1mg/L NAA (Bekheet, 2013) and (vii) 3.0 mg l/L 2-iP + 0.1 mg l/L NAA (Chander Bhan *et al.*, 2013). Direct embryo formation from shoot tip explant of date palm requires 2mg/L BA only (Abd El Bar and El Dawayati, 2014). The significant variations in the frequency of induction were found in the cultures of different genotypes and cultivars in the same medium (Beauchesne, 1982) indicate their necessity of specific culture medium for each genotype. Induction requires the culture requires low light intensity (1000-1400 lux) with temperature at $27\pm1^{\circ}\text{C}$ and sub- culturing once in a month. With these efforts the number of buds obtained was 2 to 6.2 (Asemota and Eke, 2006; Khirelladha and Badar, 2007; Mater, 1990). It was also observed that explants from offshoot and inflorescence develop roots much earlier than bud initiation and the reason for this is not known (Anjarne and Zaid, 1993; Loufti, 1999).

Shoot multiplication: The shoot multiplication from the meristematic buds of date palm mainly depends on the culture conditions, growth hormones and cultivars. In most of the researchers used the same concentration of auxins and cytokinins at both bud induction and multiplication stages where the success rate was very low. The best combination and concentration of growth hormones at the stage of multiplication are; (i)10.5 μ M of NOA+5.4 μ M of NAA+5.7 μ M of IAA: 2.2 μ M of BA+ 5.0 μ M of 2iP + 4.6-23 μ M of kinetin in one case, (ii) 1.0 mg/L of NAA +1.0 mg/L of NOA : 4.0 mg/L of 2iP+2.0 mg/L of BA (Beauchesne *et al.*, 1986; Asemota and Eke, 2006; Khirellah and Badar, 2007), (iii) 0.5 mg/L of TDZ + 1.0 mg/L of 2iP (Hussain *et al.*, 2001), (iv) 5 mg/L 2ip or/ and 2mg/L Kinetin (Bekheet, 2013) and (v) 0.5 mg/L BA + 0.5 mg/L Kinetin + 1 mg/L NAA (Khan and Bi, 2012). However, auxin and cytokinin ratios maintained less than one for the cultures initiated from young inflorescences (Loutfi and Chlyah, 1998). In this case, 2.5 μ M of NAA+ 4.4 – 8.8 μ M of BA + 5 μ M of 2iP were used in the media and cultures were incubated in the light intensity of 180 $\mu\text{mol/m}^2/\text{s}$ with 16 h photoperiod. More shoots (12.6 buds) from single date palm bud were obtained where the cultures induced from shoot tip and maintained in auxin and cytokinin ratio of more than one in liquid media with shaking (40 rpm) for 8 weeks compared to solid media (Khirellah and Badar, 2007). The multiplied date palm shoots at this stage resembled rosette.

Shoot elongation and rooting: This stage also depends on hormones used in the media and other cultural conditions. This process involves the transfer of multiplied shoot buds into a medium with high auxin: cytokinin ratio (Beauchesne *et al.*, 1986; Loutfi and Chlyah, 1998). Combination of 5.4 μ M of NAA + 2.2 μ M of BA + 2.3 μ M of kinetin or 10.8

μM of NAA + 4.4 μM of BA (or 5.0 μM of 2iP) was found optimum for elongation. GA₃ of 3-9 μM also used for 15 – 20 days during first and second subculture in order to improve shoot elongation (Loutfi, 1989). However other studies revealed that GA₃ (0.1-0.5 mg/L) alone or in combination with NAA (0.1 mg/L) were used to elongate the shoot (Khirellah and Badar, 2007; Abul-Soad *et al.*, 2006). Generally, shoot elongation takes place within 2 months. No special medium is required for rooting as date palm forms root easily during elongation time. If not, it has been suggested that the roots can be induced by adding 0.1 – 1.5 mg/L of NAA into the elongation medium (Abul-Soad *et al.*, 2006; Shakyia and Saker, 1998; Khan and Bi, 2012; Bekheet, 2013).

Acclimatization: Acclimatization of date palm plantlets derived from tissue culture is the critical steps for their survival. The conditions of plants in MS medium are in low light intensity, high humidity, aseptic and mostly heterotrophic in nature. But in the field, the seedlings are exposed to high light intensity, low humidity, autotrophic in nature and in addition to that the seedling has to survive in the microbial and other organisms in a particular ecosystem. So, the gradual impose of these factors on the date palm seedlings will improve their survival rate in the field. It has also suggested that the plantlets with root and shoot transferred to high sucrose (100 g/l) medium (Beauchesne *et al.*, 1986) before taken to the soil get more vigor and seemed to adopt well in green house during hardening stage. The gradual lifting of plastic cover in the culture room and greenhouse assists in the formation of cuticle layer and regulation of stomatal activities. Among the methods used for acclimatization of date palm seedlings the mixture containing 2 part peat moss: 1 part perlite or equal volume of peat moss and vermiculite under high humidity were found best and 80 per cent of plants were survived in the field after three months (Khirellah and Badar, 2007; Bekheet, 2013).

Embryogenesis

It is the process or phenomenon of induction of embryogenic culture and the development of somatic embryo from these date palm cultures, and utilized various explants (Reynolds and Murashige, 1979). The breakthrough came in 1979 when Tisserat (1979) used growth media supplemented with high concentration of auxins (2, 4-D) and activated charcoal and produce date palm plantlets successfully. Since then, this technique has been used effectively by various commercial laboratories producing date palm micropropagation by somatic embryogenesis mainly located in Israel, UAE and other Arab countries, USA, UK, French, Egypt and Morocco (Loutfi and El Hodami, 2005; Jain, 2007). There are several research groups have demonstrated the micropropagation of

date palm plant through somatic embryogenesis (Taha *et al.*, 2001; Sane *et al.*, 2006; Esraghi *et al.*, 2005; Eke *et al.*, 2005; Fki *et al.*, 2003; Bhargava *et al.*, 2003; Alkhateep, 2008; Alkhayri, 2003; Kackar *et al.*, 1989; Yadav *et al.*, 2001; Bekheet *et al.*, 2008; Asemota *et al.*, 2007; El-Bellaj, 2000; Loutfi, 1999; Sharon and Chandramati, 1998; Sharma *et al.*, 1986; Mater, 1986; Zaid and Tisserat, 1983; Othamani *et al.*, 2009a; Sidky and Eldawyati, 2012). Somatic embryogenesis method is ideal one for clonal propagation of woody and fruit plant (Jain and Gupta, 2005) and it has huge potential for large scale propagation of date palm because of its automation, long term storage and amenable for genetic manipulation (Jain, 2007). Somatic embryogenesis involves several steps viz., induction of callus from explants, maintenance and pro-embryogenic calli, development and maturation of somatic embryo, germination of somatic embryo and acclimatization. The summary of some important examples are given in Table 1.

Induction of callus from explants: This phase involves the conversion of differentiated tissue into dedifferentiated tissue, which is group of cells called callus. Several factors such as type and age of explants, genotypes, plant growth medium, additives, growth regulators and other cultural conditions including agents like surface sterilizing agents, fungicides and bactericides etc. which are very critical for successful induction of date palm embryogenic culture. Importantly callogenesis phase is heavily depends on genotypes used (Sane *et al.*, 2012).

Explants: Various explants have been used to initiate callus from date palm. The explants used were shoot tip of young seedling and offshoots of 1-3 year old (Taha *et al.*, 2001; Mater, 1990; Sane *et al.*, 2006; Esraghi *et al.*, 2005; Eke *et al.*, 2005; Bhargava *et al.*, 2003; Tisserat, 1979; Alkhateep, 2008; Kackar *et al.*, 1989; Yadav *et al.*, 2001; Bekheet *et al.*, 2007; 2008; El-Bellaj, 2000; Loutfi, 1999; Sharma *et al.*, 1986; Zaid and Tisserat, 1983; Veramandi and Navarro, 1996; Letouze *et al.*, 1998; Khan *et al.*, 1983; Al-Khayri, 2011), inflorescence (Fki *et al.*, 2003; Tisserat, 1979; Tissert and DeMason, 1980; Drira, 1981; Sidky and Eldawyati, 2012; Abdul-Soad and Mahdi, 2010), mature and immature zygotic embryos (Bekheet *et al.*, 2008; Mater, 1986), leaf segments excised from seedling and offshoots (Fki *et al.*, 2003; Poulain *et al.*, 1979; Yadav *et al.*, 2001; Khan *et al.*, 1983; Othmani *et al.*, 2009a; Kurup *et al.*, 2014), leaf and meristematic tissues excised from *in-vitro* grown date palm plants (Jain, 2007), auxiliary bud (Khan *et al.*, 1983; Quarishi *et al.*, 1997), stem, young merisematic roots (Sharma *et al.*, 1988; Zaid and Tisserat, 1983; Khan *et al.*, 1983; Yadav *et al.*, 2001). The most frequently used explants are apical shoot tip and lateral buds as they are more response in callus induction and other downstream process (Jain, 2007).

Culture medium: It is essential to supply adequate nutrients to the date palm tissue during *in-vitro* conditions. The most common media used for micropropagation of date palm through somatic embryogenesis is MS medium. Rarely, B₅ medium (Bhargava *et al.*, 2003; Abdul-Soad and Mahdi, 2010), Eauwan's medium (Asemota *et al.*, 2007), RM 1965 medium (Bekheet *et al.*, 2007), W and WPM medium for date palm cv. Khusab, SH and NN medium for cv. Berny and SH, W and MS medium for cv. Barhee (Al-khayri, 2011) are used in date palm tissue culture. Several research groups modified its composition upto some extent by adding additives for various purposes like vitamins, adenine sulphate, thiamine, glycine, glutamine, myo-inositol, silver nitrate (Al-khayri and Albrany, 2007) and other substances like asparagine, di-hydrogen ammonium nitrate and casein hydrolysate (Abdul, Rahim *et al.*, 2001; Letouze, 1998), date syrup (Alkhateep, 2008) and biotin (Sane *et al.*, 2006) are used for callus growth and development. Activated charcoal and poly vinyl pyrrolidone are being used to reduce tissue browning due to phenolics. Citric acid and ascorbic acid are used as antioxidant. Sucrose 20-30 g/l used as carbon and energy source in tissue culture media in addition to that date palm syrup of 5-6 per cent also replace or along with sucrose found enhance the callus growth and multiplication. In most cases, agar (0.7-0.8 %) used as gelling agent of the medium for date palm tissue culture, phytoigel is also used, but in limited level. KNO₃ is essential source of nitrogen form for callogenesis for optimum callus formation (50 mM including ammoniacal source) (Asemota, 2007).

Hormones: Generally high concentration of auxin used in most of the cases to induce callus, where auxin and cytokinin ratio also maintains high. Among plant growth regulators, 2, 4-D is commonly used either alone or in combination with cytokinin in the date palm tissue culture medium. Other auxins like picloram, NAA and NOA also used. Earlier researchers used relatively high concentration of 2, 4-D (450.5-901.0 µM) in the medium with activated charcoal for callus induction (Loutfi and El-Hadrami, 2005). Recently, several studies also have showed that less concentration of 2, 4-D is also enough to induce callus and further enhanced by addition of BA or adenine sulfate (Sane *et al.*, 2012). Based on the reports, 2, 4-D concentration up to 100 mg/l with 3-5 mg/L of BA/2iP alone or with 0.5 mg/L kinetin was found effective (or) 0.1mg/L of IAA/10 mg/L of NAA/ 4.0 mg/L of IBA with 1-3 mg/L of either BA/ 2 iP/ Kinetin or 53.7 µM NAA + 7.4 µM 2iP was also found to induce date palm callus (Al-Khayri and Al-Bahrany, 2003; Hussain *et al.*, 2001; Khan *et al.*, 1983; Asemota *et al.*, 2007; Al-Khayri, 2003; Al-khayri, 2011; Kurup *et al.*, 2014) or equal concentration of IAA and kinetin with 2,4-D also produce callus (Mater 1986; Abdul-Soad and Mahdi, 2010). Recent reports suggest that the

usage of lower concentration of 2,4-D (10 mg/L) would be beneficial for callus in induction, and other down stream process (Othmani *et al.*, 2009 a,b&c).

Surface sterilization: To avoid microbial contamination, outer surface and other endophytic organism frequently contaminate the tissue and not amenable for *in-vitro* culturing and other process. The surface sterilizing agents like HgCl₂ 0.01-0.1 per cent for 5 minutes to 1.0 hrs (Kacker *et al.*, 1989; Yadav *et al.*, 2001; Fki *et al.*, 2003; Al-Khayri and Al-Baharany, 2003; Bhargava *et al.*, 2003; Othmani *et al.*, 2009a) or 2-5 per cent NaOCl for 10-20 minutes (Eshraghi, *et al.*, 2005; Alkhateeb, 2008; Asemota *et al.*, 2007; Bekheet *et al.*, 2007) were used in most cases. Some researchers used 70 per cent ethanol for surface sterilization for 1-2 minutes with HgCl₂ and with NaOCl treatments (Bekheet *et al.*, 2007). After surface sterilization tissue were washed three times with sterilized distilled water.

Cultivars: Several cultivars of date palm used for somatic embryogenesis are; Zaghlool (Taha *et al.*, 2001), Deglet Nour (Fki *et al.*, 2003) Sukari, Barhee, Kalas (Rao *et al.*, 2001), Amsekshi (Sane *et al.*, 2006), Khuneizi (Al-Khateep, 2008; Kurup *et al.*, 2014), Mardarsing (Eshraghi *et al.*, 2005), land race like Zebia and loko (Eke *et al.*, 2005), Suckary (Al Khateep, 2008), Khadrawy (Yadav *et al.*, 2001; Kacker *et al.*, 1989), Halawy, Medjool (Yadav *et al.*, 2001), Sayar (Bhargava *et al.*, 2003), Barhy (Al-Khalifah *et al.*, 2006; Smith and Aynsley, 1995), Deglet Bey (Othmani *et al.*, 2009a), Khusab, Berny and Barhee (Al-Khayri, 2011) Gulistan (Abdul-Soad and Mahdi, 2010). More than 50 cultivars imported from various countries since 1985 to standardize somatic embryogenesis protocol for multiplication (Letouze *et al.*, 1998). Those are Barhi, Khalas, Zahidy, Medjool (from USA), Barhi, Khalas, Nabtha Saif, Kowaiz, Owaid, Halawy, Umm Dahan, Saggai, AbuMan, Rothna (from UAE), Medjool (from Morocco). After surface sterilization, explants of date palm were cut into appropriate size generally 0.4 to 10 mm as callus induction requires cut ends of tissue and placed on appropriate culture medium. These cultures are incubated in dark for 4-6 months at 25 -30°C for callus induction. Callus induction period varied from minimum of three months (Rao *et al.*, 2001) to eight months (Veramandi and Navaro, 1996) depending upon many factors and cultural conditions. Most of the cultures induced callus in dark but dim light also favours callus induction (Reuveni and Kipnis, 1974). During this period the cultures were subcultured once in a month. However, the duration of subculture varies according to the conditions and other factors including genotype, medium composition, growth regulators, etc. Minimum period of subculturing was reported from one week (Rao *et al.*, 2001) and maximum of two months (Fki *et al.*, 2003). Embryogenic potential of developed calli again depends on

the genotypes and explants derived from offshoot or inflorescence (El hadrami *et al.*, 1995; Loutfi, 1999), etc. The exact place of callus induction in the explant has been reported and probably from the vascular tissues particularly vessels (Sane *et al.*, 2006). These induced calli are so-called primary calli. Chopping of these primary calli grow fast and produce friable globular calli which more amenable for embryo induction. But what is/are factor(s) involving in the reactivation of somatic cells at the beginning in inducing callus is not known.

Maintenance: It involves induced calli from date palm explants need to be further multiplied to increase the size and developing calli should be pro-embryogenic in nature. During maintenance, the induced calli can be multiplied in the same medium and compositions used for induction. Several factors contributing to multiplication phase have been identified by many research groups. They are: (1) proliferation of calli and further formation of embryo depends on hormone concentrations. At this phase the calli should be maintained in low auxin and cytokinin like (i) 0.45 μ M of 2, 4-D and 2.2 μ M of BA (El Hadrami *et al.*, 1995); (ii) 2.5 mg/L of 2,4-D with 0.25 mg/L kinetin and 0.1mg/L NAA (Bhargava *et al.*, 2003); (iii) only auxin -1 mg/L of 2,4-D (Fki *et al.*, 2003); (iv) 2.7 μ M of NAA and 0.44 μ M of BA (Loutfi, 1999); (v) 1.5 mg/L 2ip + 10 mg/L NAA (Al-Khayri 2011) and (vi) hormone free medium (Letouze *et al.*, 1998; Yadav *et al.*, 2001; Tisserat, 1979; Sharma *et al.*, 1986; Bhaskaran and Smith, 1992; Kurup *et al.*, 2014), (2) subculturing once in a week (Rao *et al.*, 2001) to two months (Fki *et al.*, 2003) interval, most cases subculturing was done once in a month, (3) chopping of primary calli into small pieces during first or second subculturing also increased their fresh weight and growth level (Sane *et al.*, 2006; Fki *et al.*, 2003), (4) culturing of calli in liquid medium with either low auxin (0.5 mg of 2, 4-D) (Fki *et al.*, 2003) or hormone free (Letouze and Daguin, 1989; Bhaskaran and Smith, 1992). After a short period in liquid medium (up to 1 month) it can be transferred to solid medium with low auxin could increase the calli fresh weight up to 4 fold when compared to continuous subculturing in solid medium. These cell suspensions are initiated by inoculating 5g of fresh weight of friable calli in to 50-100 ml of liquid medium in 250 ml flasks with shaking (100 rpm) at $27\pm1^{\circ}\text{C}$ with 15 h photoperiod. The culture can be subcultured once in a month and each subculturing the culture was filtered through 500 μ m mesh fabric. Culture retaining this filter will be taken to next stage and the suspension culture passing this filter will be in same liquid medium for further multiplication (Letouze and Daguin, 1989). Date syrup (up to 6 %) (AlKhateep, 2008), 37.5 to 50 μ M AgNO_3 (Al-Khayri and Al-Bahrany, 2004), KNO_3 as nitrogen source in combination with ammoniacal form of nitrogen source (Asemota *et al.*, 2007) and di-hydrogeno

ammonium citrate (Letouze *et al.*, 1998) also increase the date palm callus fresh weight and development.

Somatic embryo development and maturation:

Development of somatic embryo from pro-embryogenic calli is the critical steps in somatic embryogenesis. The large scale multiplication of somatic embryo decides its applicability in commercialization/ industrialization of tissue culture raised date palm plants. Many factors and their interactions involving in the development and maturation process of somatic embryo. This includes composition of medium, growth hormones, cultural conditions and genotype/ cultivars. Most of the research groups used MS medium as base nutrient with additives. In most cases, somatic embryo formation is induced by transforming the embryogenic calli in to either hormone free medium (Al-Khayri, 2003; Rao *et al.*, 2001; Tisserat, 1979; Eke *et al.*, 2005; Letouze *et al.*, 1998; Yadav *et al.*, 2001; Kackar *et al.*, 1989; Sane *et al.*, 2006; Othmani *et al.*, 2009a&c) or low concentration of auxin, 0.1 mg/L of 2,4-D (Othmani *et al.*, 2009b), 1.0-2.5 mg/L of 2, 4-D containing media (Fki *et al.*, 2003; Bhargava *et al.*, 2003) or media containing 0.05 mg/L of NAA and 1 mg/L of 2iP (Al-Baiz *et al.*, 2000) or 0.5 mg/L NAA + 0.25 mg/L BA (Kurup *et al.*, 2014) and kept either in dark (Tisserat, 1979; Al-Khayri, 2003; Rao *et al.*, 2001; Al Khateep, 2008; Yadav *et al.*, 2001) or in low light intensity (28-50 $\mu\text{mol/m}^2/\text{s}$ or up to 300 lux) for 16 h photoperiod (Eke *et al.*, 2005; Letouze *et al.*, 1998; Fki *et al.*, 2003; Kackar *et al.*, 1989; Bhargava *et al.*, 2003). Somatic embryo also induced by culturing callus in liquid medium followed by transform them in to solid media (Fki *et al.*, 2003). During this stage, individual embryogenic cells rapidly divide and develop in to globular pro-embryo. These globular pro-embryos forms break zones with thick pecto cellulosic walls which delimited the pluricellular pro-embryos (Sane *et al.*, 2006). The anatomy of somatic and zygotic embryos is similar but the difference is the low accumulation of intracellular proteins in somatic embryo, the reason is not known. Maturation of somatic embryos is also governed by many factors and it seems that they need some stress for enough maturation. Increasing sucrose concentration (60g/l) in the medium produces large number of somatic embryos and they are large in size and stout. The similar effects also induced by using date syrup of 2.6 % (Al Khateep, 2008), intermittent culturing of somatic embryo in liquid media devoid of hormones with $\frac{1}{2}$ -strength MS medium for one month period than culturing continuously on solid medium also improves their maturation and development. It has also suggested that at this stage somatic embryo may be required less concentration of IAA (0.1 mg/L) or BA (0.1 mg/L) (Bhargava *et al.*, 2003) or silver nitrate (up to 37.5 μ M) (Al Khayri and Al-Bahrany, 2004) or partial desiccation (Fki *et al.*, 2003) or addition of 0.1 μ M of abscisic acid (ABA) (El-Bellaj, 2000) under low light

intensity for their maturation and development. During this phase, suspension culture of embryogenic calli facilitates large scale production of date palm somatic embryos (Fki *et al.*, 2003; Letouze *et al.*, 1998). Even somatic embryo require 0.5- 2.0 mg/L of 2,4-D for their further proliferation (Othmani *et al.*, 2009a).

Suspension culture method: To develop large scale, high throughput and automation production of somatic embryo is possible using suspension culture of embryogenic calli in 'bio reactor system' (Jain, 2007). The somatic embryo production through liquid culturing increased up to 20 fold (10-200 somatic embryo/ month/ 100 g of calli) (Fki *et al.*, 2003), repeated culturing of suspension culture up to three years produced 200±20 embryo/ gram of calli (Yadav *et al.*, 2001). Using temporary immersion system (TIS) shoots emerged from intact and fragmented juvenile leaf explants of date palm in RITA for 15 min per day enhanced multiplication of 8.4 shoots per shoot (Fki *et al.*, 2011). This is double the multiplication compared to solid media. Inoculation of callus of date palm cv. Barhee in MS medium with 10mg/L 2,4-D and 1.5 mg/L 2ip and subculturing once in 4 weeks enhanced somatic embryos to the tune of 3.5 fold (Al-Khayri, 2012). Liquid MS medium supplemented with 0.1 mg/L NAA and 1.5 mg/L activated charcoal enhanced 6-16 fold somatic embryos production within 16 weeks (Ibraheem *et al.*, 2013). MS media with 0.1 mg/L NAA + 0.05 mg/L BA was found optimum for suspension culture for date palm cv. Halawy and Khalas (Anonymous, 2014).

Somatic embryo germination: Matured date palm somatic embryos can germinate on the medium used for its development and maturation. The germination also occurred in hormone free medium (Rao *et al.*, 2001) with little success. However, it has been well documented that addition of NAA @ 0.1-2.0 mg/L (0.54 µM) to the growth medium increased the germination and other development of plantlets (Kacker *et al.*, 1989; Yadav *et al.*, 2001; Fki *et al.*, 2003; Eke *et al.*, 2005; Sane *et al.*, 2006; Khan *et al.*, 1983; Mater, 1986). Along with NAA, addition of cytokinin like BA @ 0.1 to 2.0 mg/L also increases the germination of date palm somatic embryo (Khan *et al.*, 1983; Kacker *et al.*, 1989). Addition of only BA @0.1mg/L (Bhargava *et al.*, 2003) or IBA @ 0.2-0.4 mg/L (Al- Khayri, 2003) or 0.1 mg/L 2,4-D (Othmani *et al.*, 2009a) or 0.1 mg/L NAA + 0.1 mg/L kinetin (Abdul-Soad and Mahdi, 2010) also induced the germination. Germination of somatic embryo was also obtained in MS medium supplemented with 1 mg/L NAA + 0.1 mg/L 2,4-D (Othmani *et al.*, 2009b) and 0.1 mg/L NAA alone (Al-Khayri, 2011) or with 0.25 mg/L BA (Kurup *et al.*, 2014). Reducing moisture content of the somatic embryos from 90 to 75 per cent by desiccation and cutting back of tip of the somatic embryo increases the rate germination from 25 to 80 per cent (Fki *et al.*, 2003). During

culturing, the cotyledon sheath elongate to several centimeter and split open, by which the plumule pierced out from and radicle also come out (Tisserat *et al.*, 1979).

Acclimatization: Date palm seedlings have 10-15 cm long with two to three leaves with distinct tap root with two to three tap root stage is suitable to transfer in to soil. Before transfer in to greenhouse, the plantlets kept in pre-acclimatization chamber with 3.87 cm² air chamber area increases the survival rate to 92 per cent in the field (Bhargava *et al.*, 2003). Some of the critical factors i.e., environmental conditions, composition of soil, and pesticide treatment against insect pest and disease causing organisms (Loutfi and El Hardrami, 2003) are important for survival of date palm plantlets. The acclimatization procedures are similar to that of plantlets derived through organogenesis. Other methods also suggested for initial planting is mixing of peat and gravette or peat mass and vermiculite in equal proportions. First 2 to 3 weeks the seedlings must be kept in high levels of relative humidity and gradually brought to glasshouse conditions. During this period, 25-30°C temperature can be maintained. The hardening takes for several months in the field. The two months old date palm plantlets regenerated from somatic embryos were transferred to pot mixer of peat moss and sand (2:1 ratio) or soil: peat moss: vermiculite (1:1:1) of equal ratio (Al-Khayri 2011) or peat: sand: dehydrated cow manure (1:1:1 ratio) (Kurup *et al.*, 2014) and cultivated in green house under natural sunlight with 25±2°C and 80-90% RH. Under this process, 60.2% of plantlets were survived in the field (Othmani *et al.*, 2009a&b; Kurup *et al.*, 2014).

Problems and possible solutions in micropropagation:

There are many problems during micropropagation of date palm through tissue culture (Table 1). The important problems are described under.

During in-vitro culturing

Tissue browning: This is one of the major problems in date palm tissue culture not only in date palm and in all the species belongs to the family *Arecaceae*. It includes browning of date palm explants and the adjacent media, which is assumed to be due to the oxidation of polyphenols like caffeoyl shikimic acids (190 to 430 µg/g of fresh weight) in to quinones. Quinones are more toxic to the tissue than phenol (Maier and Metzlium, 1965). The high content of methoxy-substituted phenols i.e., sinapic and ferulic derivatives have been associated with cell wall rigidity and loss of cell division together tissue browning (El-hardrami *et al.*, 1995). To minimize tissue browning, several additives and practices are being followed. These include incubation of culture in dark, frequent subculturing, pre-soaking of explants in antioxidant like solution containing citric acid (150 mg/L) and ascorbic acid (100 mg/L) solution before

surface sterilization (Zaid and Tisserat, 1983; Othmani *et al.*, 2009a), adding these antioxidants and addition of combination of absorbents like citrate, adenine, and glutamine (Rhiss *et al.*, 1979), or addition of activated charcoal or poly vinyl pyrrolidone (PVP) to the culture medium. Among all these additives, use of activated charcoal is more preferable to reduce tissue browning as others are toxic to plant tissue at higher concentrations. The charcoal has been used by most of the researchers to control tissue browning. It was also suggested that the medium should be added with high concentration of growth regulators when activated charcoal added to the medium (Fridborg and Erikson, 1975).

Microbial contamination: In addition to the normal tissue culture contaminants like bacteria and fungi, the endophytic microorganisms living inside date palm tissue including the meristem are also growing along with explants and contaminate the cultures. Such endophytes, *Bacillus circulans* was identified in date palm tissue culture initiated from offshoot tissues (Bouguedoura, 1993). Antibiotics such as gentamycin are often used to control such bacteria. However, the success was not appreciable (Chekaoui, 1997). In some cases, tissues are also not able to differentiate into callus when the antibiotics are added to the media. Most of the fungal contaminants identified in date palm tissue culture are *Aspergillus*, *Alternaria* and *Penicillium* and bacteria are *Bacillus*, *Staphylococcus* and *Proteus* (Abass, 2013 a & b).

During ex-vitro culturing

The plants derived through tissue culture are exhibit genetic variation or somaclonal variations and showing abnormalities in the field.

Somaclonal/ genetic variations: This is one of the major limitations in micropropagation of plants through somatic embryogenesis. Somaclonal variation has the characters of induced mutagenesis that may be strongly influenced by oxidative stress at excision of the tissue and also genotype dependant. It is influenced by technique used for propagation, nature of mother plant (chimera), types of growth regulators used, type of explant used (ploidy gradients: apex to root), age of cultures (more than one year), medium composition and incubation conditions (Zaid and Arias-Jimener, 2002). The *in-vitro* production of date palm plants by somatic embryogenesis requires the application of high concentrations of auxins like 2, 4-D or NAA for callus induction, which are known to be associated with genetic instability in date palm and other plants. DNA methylation or activation of retro-transposable elements expression or both during stress may be associated with this genetic change (Jain, 2001). To reduce somaclonal variation in tissue culture raised date palm plants, the ratio between

explants and the number of plants raised should be maximum of 1 : 2000 (Sivalingam *et al.*, 2014).

Abnormalities in the field: Tissue culture raised date palm plants showing various kinds of abnormalities like hapaxanthic axillary shoot (shoot which produce terminal inflorescence after 1-2 year growth and then die) (Sudharsan *et al.*, 2001; Sudharsan and El-Nil, 2004), twisted inflorescence, broader leaves, excessive vegetative growth, leaf variegation, dwarfing, leaf whitening, bastard offshoots, delayed flowering time, pollination failure, abnormal fruiting and seedlessness (Zaid and Al-Kaabi, 2003; Cohen *et al.*, 2004).

Possible Solutions: The variation and abnormalities found more in date palm plants produced via somatic embryogenesis than organogenesis. These somaclonal variations and abnormalities can be minimized by scanning the nature of the genome by molecular tools and enzyme analysis techniques before planting to the field. The enzyme analysis techniques like isozyme analysis of peroxidase, shikimat dehydrogenase, acid phosphatase, esterase, polyphenol oxidase (Zirdar *et al.*, 2008), and DNA fingerprinting techniques through markers like Random Amplified Polymorphic DNA (RAPD) (Letouze *et al.*, 1998; Saker *et al.*, 2000; Saker *et al.*, 2006; Javoukey *et al.*, 2000; Ali *et al.*, 2007) and Amplified Fragment Length Polymorphism (AFLP) are techniques to identify the variations of tissue culture raised date palm plants by comparing with the mother date palm plant from where the explants were taken. Fki *et al.*, (2003) analyzed the ploidy level of date palm seedlings produced by somatic embryogenesis method using flowcytometry technique and found no change in ploidy level.

Micropropagation of date palm in India

In India, production of date palm plants by tissue culture started from 1984 by somatic embryogenesis at various research Institutions and Universities (Sharma *et al.*, 1984; 1986; 1988; Yadav *et al.*, 2001; Bhargava *et al.*, 2003; Kackar *et al.*, 1989). These plants were planted in the field of respective Institutions such as CCS Haryana Agricultural University, Hisar (cv. Khadrawy, Halawy, and Medjool), SK Rajasthan Agricultural University, Bikaner (cv. Sayar and Jagloul) and ICAR-Central Arid Zone Research Institute (ICAR-CAZRI), Jodhpur (cv. Khadrawy). None of these developed protocols were commercialized. Recently Anand Agricultural University (AAU), Anand successfully developed date palm propagation protocol through tissue culture for local elite cultivar. These plants are being evaluated under field conditions at different centres such as ICAR-Central Institute for Arid Horticulture (ICAR-CIAH), Bikaner, Date Palm Research Station, Mundra and ICAR-CAZRI, Jodhpur under ICAR sponsored net work project 'Production and demonstration of tissue culture raised plants

under three locations and collection and maintenance of elite germplasm of date palm'. Under these project AAU, Anand also developing tissue culture protocol for cv. Barhee and ICAR-CAZRI for cv. Muscut-2. In addition many private companies such as ACE Biotech, Hyderabad; Atul Ltd, Jodhpur; Kachchh Crop Services Ltd, Gajod; Sarjan Biotech, Bhuj; ECO Cell, Bhuj and Saliah Dates Nursery/Dates India, Krishnapuram, are being actively involved in the production of date palm plants of different cultivars through tissue culture in India (Shah, 2014; Sivalingam *et al.*, 2014). ICAR-CIAH is also engaged in developing tissue culture protocol for date palm cv. Halawy and cv. Khalas. Suspension culture method was standardized to enhance somatic embryo formation for these date palm cultivars (Anonymous 2014).

Future perspectives

Commercial date palm micropropagation has been well established and private companies are located in Israel, UAE, USA, UK, France and Morocco. In addition to meet their local demand, it has been started exporting tissue culture grown date palm plants to other countries. The tissue culture grown plants are mostly by somatic embryogenesis, these date palm trees are in the field and yielding fruits. Some of the places have shown some variation and abnormalities in the field. This is the major challenge for companies producing date palm seedlings through tissue culture. Some method to identify the variations at the early stage has also in process such as DNA finger printing

techniques and an alternate route like production through organogenesis method to avoid variation which is already started by private companies in Morocco, UAE and Saudi Arabia. Here, the challenge is low multiplication rate. These methods of micropropagation will be highly useful in production of disease-free date palm seedlings as bayoud disease causing organism spreads through vascular tissues and causing huge economic losses to the growers. Date palm requires prolonged hot dry summer, moderate winter, rain free period at the time of fruit ripening and requires more water. In India, the north-western region includes the Thar Desert of Rajasthan, part of Gujarat and Haryana is very suitable for date palm cultivation (More *et al.*, 2011). The major bottle necks in this region are, i) non-availability of suitable cultivars for various uses, ii) non-availability of large number of planting materials, and iii) irrigation facility. Irrigation facilities in desert areas are made available through canal (IGNP) water. The main concerns which needs to be addressed are, (i) normalization of date palm tissue culture procedures for cultivars independent or develop suitable procedure for most of the necessary cultivars (ii) identification of somaclonal variation techniques precisely at early stage (before going to field) for date palm plants produced through somatic embryogenesis method (iii) reduction of time requirement of shoot bud initiation and increasing multiplication rate in organogenesis method and callus induction time in embryogenesis method (iv) methods to remove endophytic organisms which pose contamination during culturing *in vitro*

Table 1: Problems associated with the techniques used for commercial micropropagation of date palm

Types	Somatic embryogenesis	Organogenesis
Initiation	-Destruction of offshoots with the use of shoot tip meristem. -Browning of explants leading to death of tissues ($\pm 30\%$). -Length of time taken to produce nodular callus and somatic embryo approx. 6-12 months. -Use of 2, 4-D in high concentrations increasing risk of somaclonal variation - Contamination losses - Varietal response differences	-Destruction of offshoots with the use of shoot tip meristem. -Browning of explants leading to death of tissues. -Length of time for shoot proliferation is long (up to one year). -No somaclonal variation - Contamination losses
Multiplication	- Callus has limited life span and more sensitive to environmental changes - Risk of variation - Good multiplication rates (± 7) - Vitrification of callus -Unsynchronized embryo development (small and large) - Loss of totipotency in some varieties	- Yield of the technique per offshoot is low -Selection of plantlets is critical - Multiplication rates are low - Light sensitive - Loss of totipotency in some varieties - Precocious rooting sometimes occurs-decreasing regeneration capacity
Elongation	-Not necessary -Low efficient rooting (two stage rooting)	-Necessary step -Not all plants are sufficiently rooted

11.	Leaf	MS media with 10 mg/L 2,4-D	6-8 months	Othmani <i>et al.</i> , 2009
12.	Shoot tip	B5 media with 2.5-15 mg/L 2,4-D + 0.1 mg/L IAA	2-3 months	Bhargava <i>et al.</i> , 2003
13.	Leaf	Eauwan's media with 15 mg/L NAA	NR	Asemota <i>et al.</i> , 2007
14.	Tender leaf	MS media with 100 mg/L 2,4-D	2-3 months	Kurup <i>et al.</i> , 2014
15.	Inflorescence	MS media with 0.1 mg/L 2,4-D+0.1 mg/L IAA+5.0 mg/L NAA	2-3 months	Abdul-Soad & Mahdi, 2010
Somatic Embryo (SE) Formation				
1.		MS media without hormone	SE formed	Tisserat, 1979; Yadav <i>et al.</i> , 2001; Al Khayri, 2003; Fki <i>et al.</i> , 2003 ; Othmani <i>et al.</i> , 2009a&c
2.		MS media with 0.1 mg/L 2,4-D	SE formed	Othmani <i>et al.</i> , 2009b
3.		MS media with 1.0-2.5 mg/L 2,4-D	SE formed	Bhargava <i>et al.</i> , 2003; Fki <i>et al.</i> , 2003
4.		MS media with 0.5mg/L NAA + 0.25 mg/L BA	SE formed	Kurup <i>et al.</i> , 2014
5.		MS media with 5 mg/L 2,4-D + 1.0 mg/L 2iP	SE formed	Abdul-Soad & Mahdi, 2010
Somatic Embryo Germination				
1.		MS media with 0.1-2.0mg/L NAA	SE germinated	Khan <i>et al.</i> , 2003; Yadav <i>et al.</i> , 2001; Fki <i>et al.</i> , 2003; Eke <i>et al.</i> , 2005; Sane <i>et al.</i> , 2006.
2.		MS media with 0.1 mg/L BA	SE germinated	Bhargava <i>et al.</i> , 2003
3.		MS media with 0.2 – 0.4 mg/L IBA	SE germinated	Al Khayri, 2003
4.		MS media with 0.1 mg/L 2,4-D	SE germinated	Othmani <i>et al.</i> , 2009a
5.		MS media with 1 mg/L NAA + 0.1 mg/L 2,4-D	SE germinated	Othmani <i>et al.</i> , 2009b
6.		MS media with 0.5mg/L NAA + 0.25 mg/L BA	SE germinated	Kurup <i>et al.</i> , 2014
7.		MS media with 0.1mg/L NAA + 0.05 mg/L BA	SE germinated	Abdul-Soad & Mahdi, 2010

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Plant growth regulators in onion-A review

Desh Raj Choudhary^{*1} and Satesh Kumar²

¹Ph.D. Scholar, Department of Vegetable Science, CCS HAU, Hisar (Haryana)

²Division of Vegetable Science and Floriculture, SKUAST, Jammu (J&K)

*Corresponding Author's E-mail: desraj1992@gmail.com

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Abstract

Indian horticulture becomes more mechanized and science increases the possibilities for using inputs to enhance production. The discovery of plant growth substances has proved revolutionary in increasing the production of different vegetable crops. In recent years, their use becomes more vital as they provide an immediate impact on crops and are less time consuming. There is a great potentiality of various plant growth substances in different concentration for improving vegetative growth, yield and quality of onion. Further, these can also be used to prevent sprouting and rotting of bulbs in storage. This paper reviews the research work done on use of various plant growth substances like auxins, gibberellins, cytokinin, ethylene, growth inhibitors and growth retardants in onion production.

Key words: Onion, Plant growth regulators, Growth, Yield, Quality, Bolting, Shelf-life.

Introduction

Onion (*Allium cepa* L.) is one of the most important bulbous vegetable crops of India belonging to family Alliaceae and consumed worldwide. It is considered as the queen of kitchen (Selvaraj, 1976) and characterized by its distinctive flavour and pungency, which is due to sulphur containing compounds allyl propyl-disulphide, a volatile oil. Onion contains carbohydrates, protein, vitamin A, thiamine, riboflavin, niacin and ascorbic acid. It is used as salad, cooked in various ways of fried, boiled, soup making, sauces and pickles. Now-a-days white onion is also widely used in dehydrated powder form and has several medicinal properties. India is a leading producer of onion supporting 20.2% of the world production. During 2013-14, India ranked second in area (12.03 lakh ha) and production (19.40 lakh MT) after China and third in export (18.22 lakh MT) after Netherlands and Spain, with foreign exchange earnings of 1966.6 crores (Anonymous, 2014). Despite the importance of this crop it is suffering from several problems like low vegetative growth, low yield, bolting, doubling of bulbs, bulb sprouting, etc. Now-a-days the use of plant growth substances in onion has proved as a boon for improving the growth, yield, quality and shelf life of bulbs. Most of the physiological activities and growth in plants are regulated by action and interaction of some chemical substance called hormones and by some naturally occurring inhibitors. With the gradual increase of population the demand for onion is increasing day by day. To enhance onion production per hectare, improved and modern agronomic practices should be applied properly. In this connection, application of plant growth regulators (PGRs)

might be useful in increasing onion production. Recently, there has been global realization for important role of PGRs in vegetable production, better growth of crop and yield (Islam *et al.*, 2007; Bose *et al.*, 2009 and Prajapati *et al.*, 2015).

PGRs considered as a new generation of agrichemicals when added in small amounts, modify the growth of plants usually by stimulating or modifying one part of the natural growth regulatory system, thereby the yield is enhanced. The growth regulators have therefore, been known to be one of the quick means of increasing production and used in different forms like liquid, powder, paste, etc. Application of plant growth regulators in optimum concentration have given favourable impact on growth, yield and quality of onion (Maurya and Lal, 1975; Nirmal *et al.*, 1994; Singh *et al.*, 2003; Patel *et al.*, 2010; Sisodia *et al.*, 2012; Choudhary *et al.*, 2015 and Choudhary *et al.*, 2016). PGRs in onion provides professionals and researchers with the information needed to enhance production, shelf-life and quality of onion. Hence, the relevant and important published work available on onion has been reviewed and presented in this review article.

Categories and function of plant growth regulators

PGRs are organic chemical substance, other than nutrients and vitamins which regulate the growth of plant when applied in small quantities. 'Hormone' is derived from a Greek '*hormao*', which means to stimulate (Bayliss and Starling, 1902). Thimann (1948) suggested the use of term phytohormones as the organic substances, which are produced naturally in plants, synthesized in one part and

usually translocated to other part where in every small quantity affect the growth and other physiological function of the plants. They played an important role in horticulture and their function is given in Table 1.

Auxins have been used variously in horticulture which was extracted from maize kernels and identified as Indole Acetic Acid (IAA). IAA is the principal naturally occurring auxin of all higher plants and fungi. The precursor of IAA is tryptophan, an amino acid. The major sites of auxin production are the shoot tips, developing seeds and buds. There are a number of synthetic chemicals which are similar to IAA in their biological activity however, they do not occur in any plant.

Gibberellins are one of the main regulators of plant growth and development which repress the growth and promoting cell division and elongation (Tomas *et al.*, 2009). Gibberellin was first extracted from the fungus *Gibberella fujikuroi* (*Fusarium moniliforme*), the causal organism of 'foolish seedling of rice' or commonly called 'bakanae disease of rice'. It is well known that GA₃ promotes plant growth and its secondary metabolite production. They promote seed germination, leaf expansion, stem elongation and flowering initiation. Gibberellins play a major role in diverse growth processes including seed development, organ elongation, senescence and control of flowering time (Ouzounidou *et al.*, 2011). Gibberellins are designated as GA₁, GA₂ and so on. The common gibberellic acid is GA₃. At present 112 types of gibberellins are known. Gibberellins are synthesized in the young leaves (major site), shoot tip, root tip and immature seeds (embryo). Precursor of gibberellin is kaurene.

Cytokinins play a key role in the life of higher plants and responsible for cell division. Usually Zeatin is the most abundant naturally occurring free cytokinin. Zeatin is synthesized from mevalonic acid and adenine. Root tip is an

important site of cytokinin synthesis. However, developing seeds and cambial tissues are also the site of its biosynthesis. Functional activity of cytokinins occurs in the presence of auxins.

Ethylene is the simplest organic compound which affects plants. It is a natural product of plant metabolism and active in trace amounts. Ethylene is highly effective in inducing fruit ripening and called as ripening hormone. Methionine (an amino acid) is an immediate precursor of ethylene. Meristematic and nodal regions are most active in ethylene biosynthesis. Its production increases during leaf abscission and flower senescence, as well as during fruit ripening.

Growth inhibitors are synthetic or natural substances which suppress the growth of plants. They inhibit the transport of auxins and also called anti-auxins. Absciscic acid (ABA) is one of the wide spread and naturally occurring inhibitor found in plants. ABA is known as dormancy inducing and abscission accelerating substance. It is found in all parts of the seed namely the seed coat, embryonic axis, cotyledons and endosperm. ABA is synthesized in mature leaves and fruits.

The terms growth retardants is used for all chemicals that retard cell division and cell elongation in shoot tissues and regulate plant height physiologically without formative effects (Pgrsa, 2007). The formation of leaves, flowers and fruits remain unaffected. Growth retardation is primarily induced by inhibition of gibberellin biosynthesis and therefore also called anti-gibberellins. These are synthetic only. Cycocel (CCC) is an important plant growth retardant used for inducing dwarfism in plants and shorter internodes, stronger stems and green leaves. The response of CCC can vary depending on the dose or concentration, method, site of application, species and cultivar and also growing season (Taiz and Zeiger, 2006).

Table 1. Important plant growth regulators and their function

Class of PGRs	Important PGRs	Function
Auxins	Indole-3-acetic acid (IAA), Indole butyric acid (IBA), 2-Naphtalene acetic acid (NAA), Para chlorophenoxy acetic acid (PCPA)	Apical dominance, root induction, control of fruits drops, flowering regulation, parthenocarp, phototropism, geotropism, herbicides, inhibit abscission, increase female flowers and induce rooting.
Gibberellins	Gibberellic acid (GA ₃)	Stimulate cell division, cell elongation and germination of seeds. Stimulates bolting/ flowering in response to long days. Prevent genetic dwarfism, increase flower and fruit size. Break dormancy. Induces maleness in dioecious flowers. Extend self life.
Cytokinins	Kinetin, Zeatin	Promotes cell division, cell enlargement and cell differentiation. Stimulate bud initiation and root growth. Help in translocation of nutrients. Prolong storage life of flowers and vegetables. Prevent chlorophyll degradation, morphogenesis, lateral bud development and delay senescence.
Ethylene	Ethrel	Induce uniform ripening in vegetables, promotes abscission and senescence of leaf.
Growth	Absciscic acid (ABA), 2,3,5-tri-	Act as plant stress hormone. Inhibit mitotic cell division. Induce

inhibitors	iodobenzoic acid (TIBA), Chlorpropham (CIPC)	bud and seed dormancy. Induces seeds to synthesize storage proteins. Stomata regulation.
Growth retardants	Cycocel (CCC), Phosphon-D, Alar, AMO-1618, Paclobutrazol (Cultar)	Slows cell division and cell elongation of shoot tissue and regulate plant height physiologically without formative effects.

Effect on growth parameters

The application of plant growth regulators has been found effective in promoting the different growth parameters in onion. Foliar application of NAA 50ppm gave the highest plant height, number of leaves, neck diameter, bulb weight, bulb diameter and yield per hectare which might be due to the fact that growth regulators stimulated the plant growth and bulb development, which has given more opportunity for carbohydrate assimilation needed for better yield (Nandekar and Sawarkar, 1992; Nirmal *et al.*, 1994; Rizk *et al.*, 1996; Singh *et al.*, 2001; Mandal *et al.*, 2003; Amin *et al.*, 2007 and Islam *et al.*, 2007). Bose *et al.* (2009) recorded the highest plant height (61.63 cm), number of leaves/ plant (10.25) with NAA 50ppm over control.

Bio-regulators like gibberellins (GA₃) have been known to play a vital role in building of plants. Overall, only GA₃ supply leads to a vigorous onion growth and yield (Ouzounidou *et al.*, 2011) those found that GA₃ promoted the total plant length of onion by 35% of the control and number of leaves/ plant of onion increased significantly under GA₃. Foliar application of gibberellins and etheph 100ppm have also been resulted in greatest increase in plant growth of onion (Nagwa *et al.*, 2013), GA₃ 50 or 60ppm (Shaikh *et al.*, 2002; Kumar and Shashidhar, 2016). Furthermore, bio-regulators had the superior effect in various growth traits of onion (Shukla *et al.*, 2007; Tyagi and Yadav, 2007; Yamaguchi, 2008; Yu *et al.*, 2009; Sisodia *et al.*, 2012 and Ouzounidou *et al.*, 2011). Lokhande *et al.* (2014) recorded increased seedling biomass due to pre-sowing soaking treatments of GA, methionine and cysteine, while, SA, 6-BA and CCC pre-treatments slightly decreased the seedling biomass.

Although, the vegetative characters like plant height, number of leaves, leaf length, percentage of fruit set and bulb size of onion have been found inhibition with paclobutrazol 80ppm (Ashrafuzzaman *et al.*, 2009), CCC 500 or 1000ppm, etheph 2000 or 2500ppm and paclobutrazol 1000 or 2000ppm (Choudhary *et al.*, 2016). The reduction in growth parameters might be due to anti-gibberellin action of other growth retardants, which might have negated the endogenous GA level, thereby hindering vital cell activities like apical growth, cell growth and elongation (Jones *et al.*, 2009).

Effect on yield parameters

PGRs have been reported to increase the bulb yield of onion. The treatment with GA₃ and their physiological action was found to enhance vegetative growth, yield and

dry weight (Islam *et al.*, 2007). The GA₃ and NAA induced cell division and rapid cell elongation in growing portion causing increase in bulb size. NAA 30ppm resulted in maximum neck diameter (1.98 cm), fresh weight of bulb (78.71g), bulb diameter (5.08cm) and yield/ ha (337.17 q) over control (Bose *et al.*, 2009). An increase in onion bulb yield after the application of GA₃ was observed by Shakhda and Gajipara (1998), Anant and Maurya (2001), Poonam *et al.* (2002) and Subimal *et al.* (2003).

Patel *et al.* (2010) observed significantly increased volume of bulb, equatorial and polar diameter of bulb as well as bulb yield with GA₃ 50ppm while average weight of bulb was significantly increased in GA₃ 100ppm applied as root dipping + foliar spray. Foliar spray of GA₃ 80ppm and NAA 50ppm at 40 and 60 DAT produced significantly higher bulb yield of 316.7 and 311.5 q/ha, respectively, which was 24.7 and 22.7% higher over control (Sharma *et al.*, 2013). Shafeek *et al.* (2013) found the highest plant growth and total yield of onion with application of etheph 200ppm. Nagwa *et al.* (2013) recorded superior effect of GA₃ or etheph @ 100ppm on total yield of onion. The root dipping and foliar spray of GA₃ 50 or 100ppm as significantly increased bulb weight, equatorial and polar diameter of bulb as well as bulb yield (Patel *et al.*, 2010), GA₃ 500ppm (Safdari *et al.*, 2014). Similar effect of different PGRs was also reported by various researchers in onion (Demiral and Turkan, 2005; Hussein and El-Greadly, 2007; Shukla *et al.*, 2007; Tyagi and Yadav, 2007 and Sisodia *et al.*, 2012).

GA₃ promoted increased the fresh and dry weight of onion significantly under GA₃ (Ouzounidou *et al.*, 2011). Furthermore, Choudhary *et al.*, 2016 obtained the decreased bulb yield with foliar application of CCC (500 or 1000ppm) and etheph (2000 or 2500ppm). The reduction of yield is might be due to the decreased vegetative growth, bulb weight, bulb diameter and bulb size due to exogenous application of growth retardants to restrictive growth, less nutrient conceptions and low carbohydrate synthesis by the plant and subsequently reduced yield (Deore and Bharud, 1990; Hye *et al.*, 2002). Singh *et al.* (2003) recorded significantly highest plant height, bulb diameter, bulb size index, bulb weight, gross yield and marketable yield with Cytozyme 0.2% applied as root dip + spray of CCC 500ppm at 75 DAP.

Effect on quality parameters

Plant growth regulators have also been found to affect bulb quality of onion. Sharma *et al.* (2013) reported

that foliar spray of GA₃ 80ppm and NAA 50ppm improved of quality parameters of onion. Wei *et al.* (2011) also reported that GA₃ 500ppm increased soluble sugar in onion. The foliar applications of growth regulators results in increase in carotenoid content of onion leaves might be playing important role in the protection against oxidative stress. The increased level of carotenoids will help to protect the chlorophylls and to maintain better growth and productivity of onion bulb (Kojo, 2004). The increased level of carotenoids will help to protect the chlorophylls and to maintain better growth and productivity of onion bulb.

Singh *et al.* (2003) noted remarkable improvement in total soluble solids and dry matter contents with ethephon and cytozyme over the control. The N, P and K as well as Fe, Mn, Zn and Cu contents in onion bulb tissues was highest with application of ethephol 200ppm (Shafeek *et al.*, 2013). Ganie and Solanki (2010) reported the application of 1500ppm CCC increased quality characters viz., TSS, sulphur and protein content in bulbs of *kharif* onion. Furthermore, the paclobutrazol, ethephon and CCC decreased reducing sugars, soluble proteins but increased leaf chlorophylls, proteins and sugars (Arvin and Banakar, 2002). Foliar application of gibberellins and ethephol 100ppm has also been resulted in greatest increase in quality and nutrient content of onion (Nagwa *et al.*, 2013). Shafeek *et al.* (2013) also noticed the effect of ethephol on bulb quality of onion. Lokhande and Gaikwad (2014) also obtained the significantly increased chlorophylls in response to GA, CCC, methionine and cysteine application. The chlorophyll a/b ratio was slightly altered due to PGR application while the overall carotenoid content was slightly decreased in leaves of onion. The total carbohydrate content was slightly decreased, while total sugars were slightly elevated. Choudhary *et al.* (2016) obtained highest TSS content in onion with paclobutrazol 2000ppm.

Effect on bolting

Bolting is one of the major constraints in the production of onion as it directly affects the bulb yield and quality however; it is desirable for seed production. It is frequently caused by adverse weather conditions especially low temperature. Flowering in onion was mainly induced by low atmospheric temperature ranging from 4 to 15°C. Further, higher temperature after floral initiation sometimes prevents normal development of flower stalks due to abortion of flower initials (Brewster, 1994). Growth retardants reduce bolting which might be due to the active movement of these substances from the leaves into the bulb tissues at the time of bulb maturity thereby lowering down GA₃ levels, responsible for transition for vegetative to reproductive stage (Kielak and Bielinska-Czarnecka, 1987). Helaly *et al.* (2016) found decreased in earliness of bolting and bolting period with the application GA₃ at 1000ppm and CCC at 100ppm in onion. Foliar application

of paclobutrazol and ethephon reduced bolting and shoot length but CCC increased bolting (Arvin and Banakar, 2002), paclobutrazol 2000ppm showed lowest bolting in onion (Choudhary *et al.*, 2015).

Effect during storage

Post harvest handling of onion a major issue throughout the world. Onion bulbs contain about 89% water which may be harmful in post harvest life. Moisture loss itself is a major concern in post harvest life because loss in weight during storage is directly related to economic loss. Moreover, physical injury, rotting and sprouting (re-growth) are also cause deterioration of onion bulbs, because it increases respiration rate, which consequently increase moisture loss and reduce the shelf life. In India, post harvest losses in onion are over 40% (Bhagachandani *et al.*, 1980) and could be as high as 40-50% (Maini *et al.* 1984). In general, the losses due to reduction in weight, sprouting and rotting (decay) were found to be 20 to 25, 4 to 5 and 10 to 12 per cent, respectively (Pandey, 1989).

Pre-harvest sprays PGRs/ chemicals like ethephol, CCC, carbendazim and aureofungin have been widely applied without impairing the keeping quality of onion. These compounds greatly facilitate the maintenance of quality of onion bulbs in storage with respect to inhibition of sprouting, rooting and reduction in the physiological loss in weight. Several chemicals have been tried so far to prolong the shelf life of onion and a few among them are ABA, GA₃, auxin, cytokinin, MH, CCC, ethephol and paraquat (Pandey, 1989). Ethylene can suppress sprouting while the ethylene binding inhibitor 1-methylcyclopropene (1-MCP) can also suppress sprout growth and has been found to increase shelf life of onion (Cools *et al.*, 2011), with ethylene and 1-MCP in combination after curing for 24 hour (Johnson, 2006), with 1-MCP for 24 hour after curing (Chope *et al.*, 2007). Application of ethephon to onion plants 2 week prior to harvest was found to reduce sprout incidence (Adamicki, 2004).

Benkeblia and Selselet-Attou (1999) found that sprouting of the control bulbs and the non-cooled bulbs treated with ethephon were normal during storage, with a level of 50% after 3 month and 100% after 6 month. Sprouting occurred earlier for cooled bulbs treated with ethephon, 50% after 2 month and 100% after 4 month. Patel *et al.* (2010) observed the significantly reduced physiological loss of weight, spoilage loss and finally total loss with NAA 100ppm as root dipping treatment. Anbukkarasi *et al.* (2013) also reported that with CCC, ethylene and fungicides play a crucial role in delaying sprouting and enhancement of shelf life in onion. Anbukkarasi *et al.* (2013) and Banuu Priya *et al.* (2014) reviewed the work done on pre and post-harvest treatments in onion to extend shelf-life. The maleic hydrazide (MH) was banned by government of India during the year 2009.

So application of MH for postharvest handling of onion is not included in this review.

Effect on male sterility

Some PGRs induce male sterility in plants and called as gametocides. Gibbrellin was found to act as gametocide and application of GA₃ induced male sterility in onion which can be used for F₁ hybrid seed production (Prajapati *et al.*, 2015).

Conclusion

The available literature reveals that application of plant growth regulators enhances growth, yield, quality and shelf-life of onion when applied suitable dose at proper stage. Thus, it can be concluded from this review that the use of plant growth regulators in onion improve different growth, yield and quality parameters. Further, post harvest losses like rotting and sprouting of onion are major issues which can also be reduced with the application of PGRs at appropriate stages.

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Path coefficient analysis of seed yield in coriander (*Coriandrum sativum* L.).

D. Sharma, I.S. Naruka and A.K. Soni*

Department of Plantation, Spices, Medicinal and Aromatic crops, College of Horticulture, RVSKVV, Mandsaur 458 001, MP

*Corresponding author's email: soni.anil50@yahoo.com

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Abstract

Path analysis evaluation of 45 genotypes of coriander (*Coriandrum sativum* L.) at Mandsaur (Madhya Pradesh) indicated that seeds umbel-1 had the highest positive direct effect on seed yield per plant at phenotypic as well as genotypic level. At both genotypic and phenotypic level, the highest positive indirect effect on seed yield was exerted by test weight via seeds umbel⁻¹ followed by umbellet umbel⁻¹ via seeds umbel⁻¹. While the highest negative indirect effect on seed yield was imposed by days to 50 percent flowering via seeds umbel⁻¹ followed by oil percent in seeds via seeds umbel⁻¹. So path coefficient analysis revealed that seeds umbel⁻¹, test weight, umbellet umbel⁻¹ and early flowering were the most important characters for selection in coriander genotypes.

Key words: coriander, direct effect, indirect effect, Path coefficient, seed yield.

Introduction

Coriander (*Coriandrum sativum* L.) is an annual herbaceous plant belongs to the family Apiaceae. It is a native of Mediterranean region and cross pollinated diploid species, possesses $2n = 22$ chromosomes. In India, coriander is cultivated in about 543.00 thousand hectare with annual production of about 524.0 thousand MT, (Anon., 2013). The major coriander growing states are Rajasthan, Madhya Pradesh, Andhra Pradesh, Gujarat, Bihar, Uttar Pradesh and with scattered pockets in Tamil Nadu, Orissa, Karnataka and Haryana (Singh *et al.* 2013). Coriander has several potential health benefits like cholesterol-lowering, anticancer effect, anti-hypertensive, antioxidant activity, digestive stimulant and many more. This potential can further be explored and exploited to develop new formulations and coriander can be used as a complete and promising functional food (Chawla and Thakur, 2013).

Crop yield is influenced by several genetic factors interacting with the environment and therefore, study of characters which are less affected by the environment, is required to construct suitable selection indices for crop improvement. The adequacy of genotypes is determined by the amount of genetic variability present in the germplasm and limited information is available in coriander on this aspect. Furthermore, information on association among different morphological characters and with seed yield is necessary for identification of suitable selection criteria for

producing high yielding varieties. In the present investigation, 45 genotypes of coriander were used to evaluate the germplasm on the basis of *per se* performance, correlation and path coefficient analysis. Path analysis facilitates the partitioning of correlation coefficient in the direct and indirect effects on yield and any other attributes. The information is expected to form the basis of designing breeding strategies to improve the yield potential of coriander.

Materials and methods

The experimental material comprised forty five diverse genotypes (UD-7, MD Local-1, UD-176, UD-7, MDLocal-2, UD-208, UD-13, MDLocal-3, UD-475, UD-19, MDLocal-4, UD-562, UD-21, MD Local-5, UD-563, UD-22, MD Local-6, UD-565, UD-31, MD Local-7, UD-663, UD-33, MD Local-8, UD-706, UD-36, MD Local-9, UD-737, UD-44, MD Local-10, UD-794, UD-56, MD Local-11, UD-801, UD-86, MD Local-12, Rcr-20, UD-104, MD Local-13, Rcr-436, UD-109, Ajmer cr-1, Rcr-684, UD-112, MD Local-14 and Rcr-728) and were sown during *rabi*, 2013-14 under the randomized block design with three replications at Horticultural Farm, Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Mandsaur (M.P.), India. Row to row and plant to plant spacing were maintained at 30 cm and 10 cm, respectively. All the agronomic package of practices was

adopted to grow a healthy crop. In each replication five plants were randomly selected and marked for observation. Observations were recorded for ten characters viz., plant height (cm), number of branches plant⁻¹, days to 50 percent flowering, umbels plant⁻¹, umbellet umbel⁻¹, seeds umbel⁻¹, test weight (g), oil content in seeds (%), chlorophyll content in leaves (SPAD value) and seed yield plant⁻¹(g). The recorded data were analyzed for path coefficient as suggested by Dewey and Lu (1959).

Results and discussion

The genotypic correlation coefficient between different character pairs was generally similar in sign and nature to the corresponding phenotypic coefficient in the experiment. However, genotypic correlation was higher in magnitude than the corresponding phenotypic correlation (Table No.1). Seeds umbel⁻¹ established maximum positive correlation with seed yield plant⁻¹ followed by test weight while days to 50 percent flowering had maximum negative correlation with seed yield plant⁻¹ both at genotypic and phenotypic level. Similar results have been reported by Singh *et al.* (2006) and Meena *et al.* (2010).

Yield is the sum total of the several component

characters which directly or indirectly contributed to it. The information derived from the correlation studies indicated only mutual association among the characters. Whereas, path coefficient analysis helps in understanding the magnitude of direct and indirect contribution of each character on the dependent characters like seed yield. Partitioning of correlation coefficient into direct and indirect effects provide information about the nature and magnitude of effects of other characters on seed yield.

Path analysis indicated that seeds umbel⁻¹ had the highest positive direct effect on seed yield per plant at phenotypic as well as genotypic level (Table 2 & 3). At both genotypic and phenotypic level, the highest positive indirect effect on seed yield was exerted by test weight via seeds umbel⁻¹ followed by umbellet umbel⁻¹ via seeds umbel⁻¹. While the highest negative indirect effect on seed yield was imposed by days to 50 percent flowering via seeds umbel⁻¹ followed by oil percent in seeds via seeds umbel⁻¹ (Table 2 & 3). So path coefficient analysis revealed that seeds umbel⁻¹, test weight and umbellet umbel⁻¹ were the most important characters for selection in coriander genotypes. These findings are in line with those Bhandari and Gupta (1991), Singh *et al.* (2005) and Singh *et al.* (2006).

Table 1. Genotypic & Phenotypic correlation coefficient of yield and its component character of coriander

Characters		No. of branches plant ⁻¹	Days to 50% flowering	umbels plant ⁻¹	Umbellet umbel ⁻¹	Seeds umbel ⁻¹	Test wt. (g)	Oil (%) in seeds	Chlorophyll Content (SPAD value)	Seed yield plant ⁻¹ (g)
Plant height (cm)	G	0.389*	0.778**	0.320	-0.376*	-0.170	-0.533**	0.224	0.190	-0.170
	P	0.315	0.691**	0.297	-0.183	-0.150	-0.444**	0.181	0.176	-0.137
No. of branches plant ⁻¹	G		0.509**	0.722**	0.128	0.059	-0.241	-0.202	0.187	0.062
	P		0.411*	0.595**	0.055	0.045	-0.186	-0.141	0.137	0.056
Days to 50% flowering	G			0.389*	-0.179	-0.417*	-0.618**	0.212	0.124	-0.421*
	P			0.368*	-0.105	-0.394*	-0.561**	0.191	0.116	-0.383*
Umbels plant ⁻¹	G				0.250	0.179	-0.344*	-0.220	0.095	0.188
	P				0.144	0.174	-0.318	-0.202	0.083	0.170
Umbellet umbel ⁻¹	G					0.247	0.320	-0.258	-0.165	0.254
	P					0.180	0.203	-0.140	-0.142	0.170
Seeds umbel ⁻¹	G						0.344*	-0.295	-0.121	0.969**
	P						0.303	-0.265	-0.114	0.945**
Test wt. (g)	G							-0.172	-0.156	0.341*
	P							-0.139	-0.122	0.320
Oil (%) in seeds	G								0.048	-0.284
	P								0.026	-0.281
Chlorophyll Content (SPAD value)	G									-0.127
	P									-0.112

** 1% level of significance

* 5% level of significance

Table 2. Genotypic path coefficient analysis showing the direct and indirect effect on seed yield of Coriander

Character	Plant height (cm)	No. of branches plant ⁻¹	Days to 50% flowering	umbels plant ⁻¹	Umbellet umbel ⁻¹	Seeds umbel ⁻¹	Test wt. (g)	Oil (%) in seeds	Chlorophyll Content (SPAD value)	Correlation with seed yield plant ⁻¹
Plant height (cm)	-0.010	0.001	0.004	0.000	-0.002	-0.177	0.009	0.005	-0.001	-0.170
No. of branches plant ⁻¹	-0.004	0.002	0.003	0.000	0.001	0.061	0.004	-0.005	-0.001	0.062
Days to 50% flowering	-0.008	0.001	0.005	0.000	-0.001	-0.434	0.010	0.005	0.000	-0.421*
Umbels plant ⁻¹	-0.003	0.002	0.002	0.000	0.001	0.186	0.006	-0.005	0.000	0.188
Umbellet umbel ⁻¹	0.004	0.000	-0.001	0.000	0.004	0.257	-0.005	0.006	0.001	0.254
Seeds umbel ⁻¹	0.002	0.000	-0.002	0.000	0.001	1.009	-0.006	-0.007	0.000	0.969**
Test wt. (g)	0.005	-0.001	-0.003	0.000	0.001	0.358	-0.016	0.004	0.001	0.341*
Oil (%) in seeds	-0.002	0.000	0.001	0.000	-0.001	-0.307	0.003	0.024	0.000	-0.284
Chlorophyll Content (SPAD value)	-0.002	0.000	0.001	0.000	-0.001	-0.125	0.003	0.001	-0.004	-0.127

Residual effect= -0.0591

Table 3. Phenotypic path coefficient analysis showing the direct and indirect effect on seed yield of Coriander

Character	Plant height (cm)	No. of branches plant ⁻¹	Days to 50% flowering	umbels plant ⁻¹	Umbellet umbel ⁻¹	Seeds umbel ⁻¹	Test wt. (g)	Oil (%) in seeds	Chlorophyll Content (SPAD value)	Correlation with seed yield plant ⁻¹
Plant height (cm)	0.035	0.004	-0.016	0.004	0.002	-0.138	-0.021	-0.005	-0.001	-0.137
No. of branches plant ⁻¹	0.011	0.012	-0.009	0.007	0.000	0.041	-0.009	0.004	-0.001	0.056
Days to 50% flowering	0.024	0.005	-0.023	0.004	0.001	-0.362	-0.027	-0.006	-0.001	-0.383*
Umbels plant ⁻¹	0.010	0.007	-0.008	0.012	-0.001	0.159	-0.015	0.006	-0.001	0.170
Umbellet umbel ⁻¹	-0.006	0.001	0.002	0.002	-0.009	0.165	0.010	0.004	0.001	0.170
Seeds umbel ⁻¹	-0.005	0.001	0.009	0.002	-0.002	0.917	0.014	0.008	0.001	0.945**
Test wt. (g)	-0.016	-0.002	0.013	-0.004	-0.002	0.278	0.048	0.004	0.001	0.320
Oil (%) in seeds	0.006	-0.002	-0.004	-0.002	0.001	-0.243	-0.007	0.030	0.000	-0.281
Chlorophyll Content (SPAD value)	0.006	0.002	-0.003	0.001	0.001	-0.105	-0.006	0.001	-0.008	-0.112

Residual effect= 0.1031

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Studies on genetic variability and character Association in Garlic (*Allium sativum* L)

B. Bhatt, A.K. Soni* and D. Sharma

S.K.N. College of Agriculture, Jobner, Distt. Jaipur-303329, Rajasthan, India

*Corresponding author's email: soni.anil50@yahoo.com

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Abstract

Genetic variability and character association analysis were estimated among sixteen genotypes of garlic for twelve characters comprised of bulb yield and its contributing characters in Randomized Block Design with three replications during Rabi-2014-15. Analysis of variance indicated presence of considerable variability for all the twelve characters. High GCV and PCV were observed for volume of bulb and weight of cloves. High estimates of heritability along with high genetic advance as per cent of mean was observed for volume of bulb and bulb yield indicating predominance of additive gene effects for these traits. The result from character association indicated that bulb yield had highly significant positive correlation with number of cloves per bulb, ascorbic acid and weight of cloves at both the levels.

Keywords: Garlic, Variability, Correlation, Genetic advance, Heritability.

Introduction

Garlic (*Allium sativum* L.) is the second most widely cultivated bulb crop, after onion. It is an important spice crop belonging to the family Alliaceae. The economic yield is obtained from its underground bulb, which is consisted of bulblets, popularly called as cloves. It has high nutritive value than other bulb crops. It is rich in protein, phosphorus, calcium, magnesium and carbohydrates. Ascorbic acid content is very high in green garlic (Pandey, 1997). Garlic contains a colourless as well as odourless water soluble amino acid called 'allin'. On crushing the clove, an enzyme allinase acts upon allin and breaks it down to produce allicin. Garlic contains volatile oil known as 'diallyl disulphide' which is the major flavouring component in garlic. It contains 0.1 per cent volatile oil and has good export potential as bulb as well as in the form of dehydrated products.

India ranks second after China in area (247.52 thousand hectare) and second in production (1259.27 thousand tonnes) of garlic with an average productivity of 5.09 tonnes per hectare (Gupta, 2014). The major garlic producing states of India are Madhya Pradesh, Odisha, Rajasthan, Karnataka, U. P. and Gujarat. India is one of the garlic exporting countries of the world. Genetic variability character association pattern and direct and indirect effects of the yield attributing characters on bulb yield is helpful for effective selection in crop improvement. Knowledge of association of different components together with their relative contributions has immense value in selection.

Materials and methods

The field experiment entitled "Genetic Variability, correlation and path coefficient analysis in garlic (*Allium sativum* L.)" was conducted at SKN College of Agriculture, Jobner (Jaipur) during rabi season of 2014-15. The experiment consists of sixteen genotypes of garlic viz., Mahadeva, Amleta, Malaypur, Kota Local, Ranikhet Local, Haldwani Local, G-1, G-41, G-50, G-189, G-282, G-323, G-384, Jaipur Local, Sonipat Local, Malakapuri. These genotypes were evaluated in randomized block design with three replications. Genotypes were sown in a plot of 1.05 m x 1.0 m size mentioning row to row distance 15 cm and plant to plant 10 cm. Cloves of healthy bulb were sown at 5-7.5 cm depth keeping their growing ends upwards, on 3rd November, 2014. All the recommended package of practices were practiced to raise a healthy crop. Five competitive plants were marked in each plot per replication and observations were recorded on these plants. Observations were recorded on these plants for plant height (cm) at ninety days after sowing, number of leaves per plant, dry weight of bulb (g), number of cloves per bulb, weight of ten uniform cloves (g), bulb yield (q/ha), neck thickness (cm), circumference of bulb (cm), volume of bulb (cc), total soluble solids (%), sulphur content of bulb (%) and vitamin 'C' (mg/100g).

The genotypic and phenotypic coefficient of variations was done by the method as suggested by Burton (1952) and Johanson *et al.* (1955), heritability (broad sense)

by Johnson *et al.* (1955) and genetic advance by Lush (1940). The phenotypic and genotypic correlation coefficients were calculated as per the methods given by Singh and Choudhary (1985). The path coefficients were obtained by following the method of Dewey and Lu (1959).

Result and discussion

Analysis of variance revealed significant differences among the genotypes for all the traits studied indicating significant variability in the materials (Table1). The range of variation was high for bulb yield (100.56-151.80 q/ha) followed by plant height at 90 DAS (41.32-71.22 cm), volume of bulb (22.26-47.26 cc), dry weight of bulb (15.73-30.66 g), number of cloves per bulb (17.06-26.44) and weight of cloves (9.20-17.80 g). A better idea can be gained by comparing the relative amount of coefficient of phenotypic and genotypic variance for the actual strength of variability. Comparison of coefficient of variation indicated that the phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the characters which indicated effect of environment on the character expression. Among all the characters high GCV and PCV were observed for volume of bulb (23.20 & 23.31) followed by weight of cloves (21.64 & 21.66) in comparison of other characters, indicating the presence of high amount of genetic variability for these traits and selection for these characters would be effective because the response to selection is directly proportional to the variability present in the experimental material. Moderated GCV and PCV were observed for dry weight of bulb, neck thickness, number of cloves per bulb, plant height at 90 DAS and bulb yield. These results are in broad conformity to earlier researchers (Korla *et al.*, 1981; Shaha *et al.*, 1990; Dhar, 2002; Agrawal and Tiwari, 2004; Singh and Chand, 2004 and Singh *et al.*, 2012). With the help of PCV and GCV alone, it is not possible to determine the amount of variation which is heritable. The heritability along with genetic advance is more meaningful and help in predicting the resultant effect of selection on phenotypic expression. Estimates of heritability in broad sense was high for bulb yield, weight of cloves, number of cloves per bulb, volume of bulb, ascorbic acid, dry weight of bulb and TSS and high heritability along with high genotypic coefficient

of variance was recorded for weight of cloves and volume of bulb. The heritability estimates along with genetic advance were more useful than heritability estimates alone in predicting the response to selection. Thus, high heritability along with high genetic advance as per cent of mean was observed for volume of bulb and bulb yield. In this condition selection will be more effective for these characters. Yield of a crop is the results of interaction of a number of inter-related characters. Therefore selection should be based on these component characters after assessing their correlation with yield.

Characters associated revealed the mutual relationship between two characters, and it is important parameter for taking a decision regarding the nature of selection to be followed for improvement in the crop under study. The phenotypic and genotypic correlation among yield and yield components in garlic are presented in Table 2. Significant correlation of characters suggested that there is much scope for direct and indirect selection for further improvement. In general, the estimate of genotypic correlation coefficient was higher than their corresponding phenotypic ones, therefore suggesting strong inherent association among the characters studied. In the present investigation, bulb yield showed significant positive correlation with number of cloves per bulb, ascorbic acid and weight of cloves. Although it showed positive and non significant correlation with sulphur content, TSS, circumference of bulb and dry weight of bulb. From these associations, it appears that higher bulb yield can be obtained by increasing these characters. Positive association of dry weight of bulb with yield of garlic was also observed by Kohli and Mahajan, 1993 and Baiday and Tiwari, 1995.

Yield is sum total of several component characters which directly or indirectly contributed to it. The information derived from the correlation studies indicated only mutual association among the characters. In the light of above findings, it may be concluded that improvement in the characters like number of cloves per bulb, ascorbic acid, dry weight of bulb, circumference of bulb and number of leaves per plant will help in improving the bulb yield in garlic. Therefore these characters should be considered for bulb yield in garlic breeding programme

Table 1. Estimates of genetic parameters of variation for the different characters of garlic genotypes

Characters	Mean	Range	Genotypic Variance	Phenotypic Variance	Genotypic Coefficient of Variance	Phenotypic Coefficient of Variance	Heritability (%)	Genetic Advance	Genetic Advance as per cent of mean (%)
Plant height at 90 days after sowing (cm)	53.22	41.32 - 71.22	47.76	56.29	12.98	14.10	84.84	13.11	24.64
Number of leaves per plant	7.52	6.73 - 8.06	0.12	0.21	4.54	6.03	56.65	0.53	7.04
Number of cloves per bulb	21.61	17.06-26.44	8.82	8.88	13.75	13.79	99.40	6.10	28.23

Weight of cloves (g)	13.38	9.20-17.80	8.39	8.41	21.64	21.66	99.78	5.96	44.53
Dry weight of bulb (g)	20.51	15.73 - 30.66	13.45	14.63	17.88	18.65	91.91	7.24	35.32
neck thickness (cm)	0.88	0.66 - 1.24	0.02	0.02	14.61	15.83	85.15	0.24	27.77
Circumference of bulb (cm)	12.28	10.42 - 14.02	1.00	1.19	8.16	8.90	83.98	1.89	15.40
Volume of bulb (cc)	34.64	22.26 - 47.26	64.61	65.21	23.20	23.31	99.08	16.48	47.58
Total soluble solids (%)	41.79	39.77 - 43.19	1.00	1.11	2.39	2.52	89.91	1.95	4.67
Sulphur content (%)	0.33	0.31 - 0.35	0.00	0.00	2.63	4.07	41.93	0.01	3.51
Ascorbic acid (mg/100g)	11.05	9.57 - 11.48	0.21	0.22	4.13	4.28	93.49	0.91	8.24
Bulb yield (q/ha)	123.84	100.56 - 151.80	231.31	231.76	12.28	12.29	99.80	31.30	25.27

Table 2. Phenotypic (P) and genotypic (G) correlation coefficients between different characters in garlic

Characters		Plant height at 90 days after sowing(cm)	Number of leaves per Plant	Number of cloves per bulb	Weight of uniform cloves (g)	Dry weight of bulb (g)	Neck thickness (cm)	Circumference of bulb (cm)	Volume of bulb (cc)	Total soluble solids (%)	Sulphur content (%)	Ascorbic acid (mg/100g)	Bulb yield (q/ha)
Plant height at 90 days	P	1.0000	0.5021**	-0.4148**	-0.4213**	-0.1700	-0.0753	0.2728	0.3462*	-0.3432*	-0.3833**	-0.6045**	-0.4709**
after sowing(cm)	G	1.0000	0.5721	-0.4540	-0.4618	-0.1954	-0.0765	0.3131	0.3735	-0.4001	-0.5217	-0.6967	-0.5071
Number of leaves per plant	P		1.0000	-0.0327	0.1531	-0.0786	0.0365	0.4376**	0.3610*	-0.1000	-0.0106	-0.0572	-0.0794
	G		1.0000	-0.0648	0.2025	-0.0900	0.0589	0.6499	0.4661	-0.0831	0.1592	-0.1289	-0.0984
Number of cloves per bulb	P			1.0000	0.3881**	0.0403	-0.1737	-0.0203	-0.0662	0.2101	0.1812	0.3910**	0.8032**
	G			1.0000	0.3907	0.0473	-0.1897	-0.0256	-0.0696	0.2246	0.2795	0.4018	0.8070
Weight of cloves (g)	P				1.0000	0.1027	0.0120	0.0494	-0.2757	0.2683	0.1894	0.4507**	0.4865**
	G				1.0000	0.1041	0.0157	0.0574	-0.2773	0.2803	0.3159	0.4668	0.4872
Dry Weight of bulb (g)	P					1.0000	-0.1270	-0.1277	-0.1604	0.1051	0.4900**	-0.2212	0.0051
	G					1.0000	-0.1525	-0.1310	-0.1602	0.0810	0.8052	-0.2295	0.0068
Neck thickness (cm)	P						1.0000	0.4908**	0.4971**	0.1039	0.1270	0.4149**	-0.0457
	G						1.0000	0.5690	0.5470	0.1159	0.2199	0.4810	-0.0444
Circumference of bulb (cm)	P							1.0000	0.6873**	-0.1053	0.1103	0.1267	0.0462
	G							1.0000	0.7555	-0.1497	0.1346	0.1138	0.0529
Volume of bulb (cc)	P								1.0000	0.0767	-0.0709	0.0882	-0.0588
	G								1.0000	0.0785	-0.0931	0.0895	-0.0587
Total soluble solids (%)	P									1.0000	0.2237	0.2980*	0.1289
	G									1.0000	0.3773	0.3575	0.1363
Sulphur content (%)	P										1.0000	0.1504	0.1759
	G										1.0000	0.1737	0.2703
Ascorbic acid (mg/100g)	P											1.0000	0.5496**
	G											1.0000	0.5729

*Significant at p=0.05 or at 5 % and **Significant at p=0.01 or at 1%

Table 3 Phenotypic (P) and genotypic (G) path coefficients of various characters on bulb yield of garlic=

Characters		Plant height at 90 days after sowing (cm)	Number of leaves per plant	Number of cloves per bulb	Weight of cloves (g)	Dry weight of bulb (g)	Neck thickness (cm)	Circumference of bulb (cm)	Volume of bulb (cc)	Total soluble solids (%)	Sulphur content (%)	Ascorbic acid (mg/100g)	Correlation with bulb yield
Plant height at 90 days after sowing (cm)	P	0.0781	-0.0849	-0.2628	-0.0893	-0.0058	0.0083	0.0078	0.0352	0.0525	-0.0138	-0.1962	-0.4709
	G	-0.0649	0.0113	-0.3105	0.0007	-0.0626	0.0034	0.0955	-0.0806	0.0072	0.1719	-0.2784	-0.5071
Number of leaves per plant	P	0.0392	-0.1691	-0.0207	0.0325	-0.0027	-0.0040	0.0124	0.0367	0.0153	-0.0004	-0.0186	-0.0794
	G	-0.0371	0.0197	-0.0443	-0.0003	-0.0288	-0.0027	0.1982	-0.1006	0.0015	-0.0525	-0.0515	-0.0984
Number of cloves per bulb	P	-0.0324	0.0055	0.6335	0.0822	0.0014	0.0190	-0.0006	-0.0067	-0.0321	0.0065	0.1269	0.8032
	G	0.0295	-0.0013	0.6840	-0.0006	0.0152	0.0085	-0.0078	0.0150	-0.0040	-0.0921	0.1606	0.8070
Weight of cloves (g)	P	-0.0329	-0.0259	0.2459	0.2119	0.0035	-0.0013	0.0014	-0.0280	-0.0410	0.0068	0.1463	0.4865
	G	0.0300	0.0040	0.2673	-0.0015	0.0334	-0.0007	0.0175	0.0599	-0.0050	-0.1041	0.1865	0.4872
Dry weight of bulb (g)	P	-0.0133	0.0133	0.0256	0.0218	0.0340	0.0139	-0.0036	-0.0163	-0.0161	0.0176	-0.0718	0.0051
	G	0.0127	-0.0018	0.0324	-0.0002	0.3206	0.0069	-0.0400	0.0346	-0.0015	-0.2653	-0.0917	0.0068
Neck thickness (cm)	P	-0.0059	-0.0062	-0.1100	0.0026	-0.0043	-0.1097	0.0140	0.0505	-0.0159	0.0046	0.1346	-0.0457
	G	0.0050	0.0012	-0.1297	0.0000	-0.0489	-0.0450	0.1736	-0.1181	-0.0021	-0.0724	0.1922	-0.0444
Circumference of bulb (cm)	P	0.0213	-0.0740	-0.0129	0.0105	-0.0043	-0.0538	0.0284	0.0698	0.0161	0.0040	0.0411	0.0462
	G	-0.0203	0.0128	-0.0175	-0.0001	-0.0420	-0.0256	0.3050	-0.1631	0.0027	-0.0443	0.0455	0.0529
Volume of bulb (cc)	P	0.0270	-0.0611	-0.0419	-0.0584	-0.0055	-0.0545	0.0195	0.1016	-0.0117	-0.0025	0.0286	-0.0588
	G	-0.0243	0.0092	-0.0476	0.0004	-0.0514	-0.0246	0.2305	-0.2159	-0.0014	0.0307	0.0357	-0.0587
Total soluble solids (%)	P	-0.0268	0.0169	0.1331	0.0568	0.0036	-0.0114	-0.0030	0.0078	-0.1529	0.0080	0.0967	0.1289
	G	0.0260	-0.0016	0.1536	-0.0004	0.0260	-0.0052	-0.0457	-0.0169	-0.0179	-0.1243	0.1428	0.1363
Sulphur content (%)	P	-0.0299	0.0018	0.1148	0.0401	0.0167	-0.0139	0.0031	-0.0072	-0.0342	0.0359	0.0488	0.1759
	G	0.0339	0.0031	0.1912	-0.0005	0.2582	-0.0099	0.0411	0.0201	-0.0068	-0.3295	0.0694	0.2703
Ascorbic acid (mg/100g)	P	-0.0472	0.0097	0.2477	0.0955	-0.0075	-0.0455	0.0036	0.0090	-0.0456	0.0054	0.3245	0.5496
	G	0.0452	-0.0025	0.2749	-0.0007	-0.0736	-0.0217	0.0347	-0.0193	-0.0064	-0.0572	0.3996	0.5729

Residual effect : Phenotypic = 0.4959 and Genotypic = 0.4974

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Impact of water stress on photosynthesis and secondary metabolites in snap melon and musk melon

Rakesh Bhargava*, Karun Gurjar, S. M. Haldhar, R. S. Singh and B. D. Sharma
Central Institute for Arid Horticulture, Beechwal, Bikaner – 334003, Rajasthan.

*Corresponding Author email : rbciah@yahoo.com

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Abstract

A study was conducted to assess the impact of water stress on physiological activities and metabolite constitution in musk melon and snap melon. The field grown plants were subjected to water stress for 5 and 10 days when the plants were 45 days old. Subsequently, the stressed plants were re-irrigated and allowed to recover up to 15 days after re-irrigation. The data on photosynthetic rate and associated parameters and secondary metabolites such as total sugar, phenols, alkaloids, tannins and flavonoid content were assessed at every stage. The data revealed that snap melon the photosynthetic rate recovered fast and nearly reached to the values in control plants, however in musk melon the recovery was low. The data on flavonoid constitution of snap melon reveals that the magnitude of this metabolite increases with imposition of stress as well as age of plants showing thereby that the plants have potential to scavenge the ROS moieties developed due to water stress.

Key words: Drought stress, secondary metabolites, Water use efficiency, Carboxylation efficiency

Introduction

Drought stress has profound effect on the physiological and biochemical process of plants. It has been documented growth and development, dry matter production and partitioning are all dependent on the water status of plant. Plant physiological process such as photosynthesis transpiration are dependent on the severity and duration of drought (Vadell and Medrano, 1992). It has been demonstrated that as soon as plants sense the drought stress, the stomata reduce the opening and hence restrict the transpiration rate (Flexas and Medrano, 2002).

Apart from this, it also reduce the internal CO₂ concentration in mesophyll cells which affects the rate of photosynthesis (Wong *et al.*, 1985; Cormic, 1994). In some plants drought also reduce the rate of photosynthesis by non-stomatal factors also such as decreased carboxylation efficiency (Ramanjula *et al.*, 1998; Rouhi *et al.*, 2007) regeneration of RuBP (Vu *et al.*, 1999) loss of RUBISCO activity (Parry *et al.*, 2002), etc.

Drought also creates oxidative stress in plants (Weidner *et al.*, 2009). This leads to production of excess of reactive oxygen species and free radicals which can be neutralized either by scavenging systems, such as superoxide dismutase, catalase and peroxidase or by involving small molecules such as glutathione, ascorbate, carotenoids, flavonoid, phenols, etc. Among various compounds present in plant tissue, phenolics and flavonoid have anti oxidative properties (Rosicka-Kaczmarek, 2004).

The antioxidative effect produced by phenols largely depends on their hydroxyl groups present in its structure.

In view of the above, the aim of the present study was to compare the physiological and biochemical activities in drought susceptible and drought tolerant species in order to assess mechanism adopted by them for drought endurance.

Material and methods

Plant Material

Snap melon (drought tolerant) and musk melon (drought susceptible) constituted the material for present study. The seeds were sown in field on 16th Feb., 2015 under recommended cultural practices. The plants were allowed to grow with irrigation up to 45 DAS. Thereafter, the plants were divided into two viz. (i) control- irrigated normally and (ii) stressed where irrigation was withheld upto 10 days. After completion of stress period, the stressed plants were re-irrigated and parameters under recovery were studied. The observation on photosynthetic rate and associated parameters and metabolite composition were recorded at an interval of 5 days during stress and after re-irrigation as presented in table 1.

Photosynthesis and transpiration measurements

Net photosynthesis rate was measured by using Infra Red Gas Analyzer (CID 340, CID Inc., USA). The observations were recorded between 8.00 AM-10.00 AM in field. A minimum of three replications were taken for each

observations. The observations were recorded at fixed CO₂ (400 ppm) and light intensity between 900-1000 $\mu\text{E m}^{-2} \text{s}^{-1}$. Beside net photosynthesis, the data on transpiration and internal CO₂ concentration were also recorded. Using the above data, values of water use efficiency and carboxylation efficiency were also calculated for respective days of observation.

Estimation of metabolite composition

For estimation of metabolite composition, leaf samples from different treatments were collected and dried. The estimations were done using the dried powder.

Total sugars

For estimation of total sugars anthrone method as described by Thimmaiah (2016) with slight modification was adopted. 50 mg of sample was hydrolyzed with 2.5 ml of 2.5N HCL in boiling water for 1.5 hrs. The tubes were cooled and neutralized with NaCO₃. The final volume was made up to 50 ml. One ml of this solution was reacted with 4 ml of anthrone reagent and heated in water bath for 8 min. Subsequently the absorbance was read at 620 nm. The standard curve was made with different concentration of glucose.

Total phenols

The total phenols were estimated by using the method described by Malik and Singh (1980). For this 0.5g of powder sample was dissolved in 10 ml of methanol. The whole set up was left at room temperature for overnight. Subsequently, it was filtered and filtrate was allowed to dry at room temperature. The residue was dissolved in 5 ml of distilled water. From this 0.5 ml of sample was taken and volume made upto 3 ml. This was treated with 0.5 ml phenol reagent and kept at room temperature for 3 min. After this 2 ml of 20% sodium carbonate was added and solution was heated in boiling water for 1 min. The blue colour so developed was read on spectrophotometer at 650 nm. The standard curve was made with catechol.

Total Flavonoid

The flavonoid content in the samples were estimated by the method described by Ebrahimzadeh *et al.* (2008). For this 0.5 gm of powder sample was dissolved in 10 ml of methanol. After 24 hrs. The whole smash was filtered and filtrate was dried at room temperature. The final volume was made upto 10 ml with distilled water. To 1 ml of this test sample, 1.5 ml methanol, 0.1 ml of 10% AlCl₃, 0.1 ml of potassium acetate and 1.8 ml of distilled water was added. The resulting yellow colour was read on spectrophotometer at 415nm.

Tannins

The tannin content in the sample was estimated by the method described by Schanderl (1970) with slight modifications. For this, 1 gm of powder sample was suspended in 30 ml of distilled water was boiled for 30 min. The whole solutions was filtered. One ml of filtrate was used as test sample by diluting with equal amount of water. To this 0.5 ml of Folin-Denis reagent and one ml of Na₂CO₃ was added and absorbance of blue colour thus produced was read at 700nm in spectrophotometer. The standard graph was made using tannic acid.

Alkaloid

For estimation of alkaloids, 2gm of sample was mixed with sufficient water so that it forms semi-solid paste. This was transferred in separating funnel and partitioned with chloroform. The pH of residues was adjusted to 8-9 by adding liquid ammonia in aqueous layer. This was again partitioned with 70 ml of chloroform and chloroform fraction was collected in pre-weights evaporating dish. From this the alkaloid content was estimated.

Results and Discussion

Photosynthesis and associated parameters

The data collected on effect of water stress on photosynthesis and associated parameters on musk melon are presented in table 1.

Table 1. Photosynthetic rate and associated parameters in musk melon under water stress and recovery

Treatment (Days after imposing stress)	Water stress				Treatment (Days corresponding to stress treatment)	Control			
	Pn ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{s}^{-1}$)	Transpiration ($\text{mmol H}_2\text{O m}^{-2} \text{s}^{-1}$)	Leaf level WUE ($\mu\text{mol CO}_2 \text{ mmol H}_2\text{O}^{-1}$)	Carboxylation efficiency ($\mu\text{mol m}^{-2} \text{s}^{-1} \text{ppm}^{-1}$)		Pn ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{s}^{-1}$)	Transpiration ($\text{mmol H}_2\text{O m}^{-2} \text{s}^{-1}$)	Leaf level WUE ($\mu\text{mol CO}_2 \text{ mmol H}_2\text{O}^{-1}$)	Carboxylation efficiency ($\mu\text{mol m}^{-2} \text{s}^{-1} \text{ppm}^{-1}$)
0	20.45	8.6	2.37	0.086	0	20.45	8.6	2.377	0.086
5	16.4	7.35	2.23	0.076	5	20.64	8.56	2.52	0.072
10	11.09	4.98	2.22	0.059	10	18.91	7.60	2.48	0.099
5 days recovery	16.1	8.25	1.95	0.084	15	19.01	8.22	2.31	0.114
10 days recovery	17.03	7.35	2.31	0.119	20	18.34	7.72	2.37	0.091
15 days recovery	17.52	7.46	2.34	0.08	25	17.85	7.65	2.32	0.864

Perusal of table 1 reveals that the photosynthesis rate at time of imposition of stress was $20.45 \mu \text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ which dropped to $16.4 \mu \text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ and $10.09 \mu \text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ after 5 and 10 days of imposition of water stress. Subsequently, on re-irrigation, the photosynthesis rate recovered and it reached to 16.1, 17.03 and $17.52 \mu \text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ at 5, 10 and 15 days after recovery, respectively. However, in controls, the photosynthetic rate was 20.45, 20.64, 18.91, 19.01, 18.34 and $17.85 \mu \text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ at 0, 5, 10, 15, 20 and 25 days after the start of experiment. Similarly, the transpiration rate in controls was 8.6, 8.56, 7.60, 8.22, 7.72 and $7.65 \text{ mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$ at 0, 5, 10, 15,

20 and 25 days after start of experiment. In the treatments, the transpiration rate was $8.6 \text{ mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$ at the start of experiment which dropped to 7.35 and $4.98 \text{ mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$ at 5 and 10 days after imposition of stress. On recovery, the magnitude of transpiration rate goes to 8.25, 7.35 and $7.46 \text{ mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$ at 5, 10 and 15 days after re-irrigation. Accordingly, the WUE of plants under treatment was 2.37, 2.23, $2.22 \mu \text{mol CO}_2 \text{ mmol H}_2\text{O}^{-1}$ at 0, 5 and 10 days after imposition of stress and was 1.95, 2.31 and $2.34 \mu \text{mol CO}_2 \text{ mmol H}_2\text{O}^{-1}$ at 5, 10 and 15 days after re-irrigation. In control plants the magnitude of WUE remained nearly same.

Table 2. Photosynthetic rate and associated parameters in snap melon under water stress and recovery

Treatment (Days after imposing stress)	Water stress				Treatment (Days corresponding to stress treatment)	Control			
	Pn ($\mu \text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$)	Transpiration ($\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$)	Leaf level WUE ($\mu \text{mol CO}_2 \text{ mmol H}_2\text{O}^{-2}$)	Carboxylation efficiency ($\mu \text{mol m}^{-2} \text{ s}^{-1} \text{ ppm}^{-1}$)		Pn ($\mu \text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$)	Transpiration ($\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$)	Leaf level WUE ($\mu \text{mol CO}_2 \text{ mmol H}_2\text{O}^{-2}$)	Carboxylation efficiency ($\mu \text{mol m}^{-2} \text{ s}^{-1} \text{ ppm}^{-1}$)
0	18.73	6.25	2.99	0.068	0	18.73	6.25	2.99	0.068
5	17.05	6.01	2.83	0.077	5	18.64	5.24	3.55	0.062
10	14.75	5.42	2.72	0.052	10	15.97	5.72	2.79	0.052
5 days recovery	19.88	7.87	2.52	0.080	5	15.92	6.83	2.33	0.059
10 days recovery	18.32	6.64	2.75	0.069	20	15.67	6.48	2.41	0.064
15 days recovery	18.64	7.09	2.62	0.070	25	14.97	6.01	2.49	0.064

Perusal of table 2 reveals that the photosynthesis rate at time of imposition of stress was $18.73 \mu \text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ which dropped to $17.05 \mu \text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ and $14.75 \mu \text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ after 5 and 10 days of imposition of water stress. Subsequently, on re-irrigation, the photosynthesis rate recovered and it reached to 19.88, 18.32 and $18.64 \mu \text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ at 5, 10 and 15 days after recovery, respectively. However, in controls, the photosynthetic rate was 18.73, 18.64, 15.97, 15.92, 15.67 and $14.97 \mu \text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ at 0, 5, 10, 15, 20 and 25 days after the start of experiment. Similarly, the transpiration rate in controls was 6.25, 5.24, 5.72, 6.83, 6.48 and $6.018 \text{ mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$ at 0, 5, 10, 15, 20 and 25 days after start of experiment. In the treatments, the transpiration rate was $6.25 \text{ mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$ at the start of experiment which dropped to 6.01 and $5.42 \text{ mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$ at 5 and 10 days after imposition of stress. On recovery, the magnitude of transpiration rate goes to 7.87, 6.64 and $7.09 \text{ mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$ at 5, 10 and 15 days after re-irrigation. Accordingly, the WUE of plants under treatment was 2.99, 2.83 and $2.72 \mu \text{mol CO}_2 \text{ mmol H}_2\text{O}^{-1}$ at 0, 5 and 10 days after imposition of stress and was 2.52,

2.75 and $2.62 \mu \text{mol CO}_2 \text{ mmol H}_2\text{O}^{-1}$ at 5, 10 and 15 days after re-irrigation. In control plants the magnitude of WUE remained nearly same.

Metabolite composition under water stress

The data on various metabolite compositions of snap melon and musk melon are presented in 3-7, under water stress and control. Perusal of data in table 3 reveals the changes in flavonoid content in musk melon and snap melon under control and water stress. The data on snap melon show that the magnitude of flavonoid was 3.16 mg g^{-1} dry weight at the start of water stress. On imposition of water stress, its magnitude increased to 4.44 mg g^{-1} dry weight and reached upto 6.55 mg g^{-1} dry weight after 10 days of stress. On re-irrigation, its magnitude declined slightly and reached back to 3.46 mg g^{-1} dry weight after 15 days of re-irrigation. However, in control conditions the magnitude increased with increase in age of crop.

The initial value of flavonoid in musk melon was 2.18 mg g^{-1} dry weight which declined with imposition of water stress to the level of 0.81 mg g^{-1} dry wt. After 10 days

of imposition of stress. On re-irrigation, the magnitude increased with age of plant. However, under control conditions, the magnitude remained nearly constant.

Perusal of data in table 4 for reveals that changes in tannin content in musk melon and snap melon under control and water stressed. Data demonstrates that in snap melon the

initial magnitude of tannin was 3.86 mg g⁻¹ dry wt. which remained nearly constant with imposition of water stress. However, on re-irrigation the value increased significantly and reached to 5.01, 5.15 and 4.9 mg g⁻¹ dry wt. on 5th, 10th and 15th days after re-irrigation. However, in control, the magnitude remained nearly constant.

Table 3. Total flavonoid content in plants under different treatment

Treatment	Total Flavonoid (mgg ⁻¹ dry wt.)					
	Day of initiation of stress	Days after stress		Days after re-irrigation		
		05	10	05	10	15
Musk melon (Control)	2.18± 0.021	1.92±0.011	2.11±0.055	2.75±0.130	1.71±0.010	1.966±0.055
Musk melon (Stressed)	2.18 ± 0.021	1.34±0.015	0.81±0.062	2.80±0.045	2.37±0.202	0.76±0.036
Snap melon (control)	3.16 ± 0.045	3.42±0.075	4.33±0.085	5.67±0.030	7.12±0.090	6.19±0.030
Snap melon (Stressed)	3.16 ± 0.045	4.44±0.087	6.55±0.133	5.186±0.106	4.36±0.096	3.46±0.140

Table 4. Tannin content in plants under different treatment

Treatment	Tannin (mgg ⁻¹ dry wt.)					
	Day of initiation of stress	Days after stress		Days after re-irrigation		
		05	10	05	10	15
Musk melon (Control)	3.24 ± 0.018	3.19±0.036	2.92±0.11	5.19±0.03	4.41±0.04	4.55±0.04
Musk melon (Stressed)	3.24 ± 0.018	2.34±0.061	3.30±0.04	5.11±0.21	5.033±0.045	4.05±0.015
Snap melon (control)	3.86 ± 0.044	3.79±0.065	3.5±0.062	5.44±0.04	5.38±0.036	5.41±0.025
Snap melon (Stressed)	3.86 ± 0.044	3.49±0.19	3.91±0.088	5.016±0.032	5.153±0.035	4.9±0.097

In musk melon under control condition, the magnitude declined slightly but remained nearly constant during stress period. On re-irrigation the magnitude increased and reached upto 5.11 mg g⁻¹ dry wt. Similarly trend was observed under control condition also.

Perusal of data presented in table 5 demonstrates the changes in total alkaloid content in musk melon and snap melon under water stress. The data reveals that in snap melon plants maintained in control conditions, the

magnitude of total alkaloid remained nearly same during the period of experiment. However, in plants under stress treatment, the magnitude increased to 2.18 mg g⁻¹ dry wt. at 5th day of water stress, but it declined on 10th days of stress. On re-irrigation, the magnitude nearly remained same as at the initial stage. In musk melon, the magnitude of alkaloid content increased from 0.78 mg g⁻¹ dry wt. at the start of experiment which increased to 1.46 mg g⁻¹ dry wt. on 5th day of experiment but further the magnitude declined.

Table 5. Alkaloid content in plants under different treatment

Treatment	Alkaloid (%)					
	Day of initiation of stress	Days after stress		Days after re-irrigation		
		05	10	5	10	15
Musk melon (Control)	0.78 ± 0.08	0.8±0.1	1.56±0.15	1.65±0.05	1.0±0.1	1.24±0.045
Musk melon (Stressed)	0.78 ± 0.08	1.46±0.11	0.78±0.07	1.27±0.07	1.46±0.06	2.71±0.206
Snap melon (control)	1.44 ± 0.09	1.23±0.15	0.8±0.05	1.2±0.1	1.47±0.07	1.246±0.05
Snap melon (Stressed)	1.44 ± 0.09	2.28±0.10	0.8±0.1	1.43±0.057	1.2±0.05	1.48±0.076

The total sugar content in the leaves of snap melon and musk melon plants under water stress is presented in

Table 6. Perusal of data on musk melon reveals that the initial value of total sugar was 34.52 mg g⁻¹ dry wt. on

imposition of water stress and subsequent recovery, the values nearly remained constant. Similar trend was also observed under control conditions. In snap melon, under control conditions, the total sugar values remained nearly constant, but on imposition of water stress the total sugar level increased from 28.62 mg g⁻¹ dry wt. To 41.63 mg g⁻¹

dry wt. on 10th days of stress. On re-irrigation the magnitude remained nearly same.

No specific trend was observed with respect to total phenolics in musk melon crop, but impositions of water stress increased the level of total phenolics in snap melon (Table 7)

Table 6. Total sugar content in plants under different treatment

Treatment	Total Sugar (mgg ⁻¹ dry wt.)					
	Day of initiation of stress	Days after stress		Days after re-irrigation		
		05	10	5	10	15
Musk melon (Control)	34.52 ± 0.48	36.12±0.13	39.0 ±1.89	32.29±0.51	43.52±1.37	37.69±1.95
Musk melon (Stressed)	34.52 ± 0.48	34.04±0.29	32.97±1.02	30.94±0.45	32.41±0.56	36.50±4.11
Snap melon (control)	28.62 ± 0.78	29.26±0.14	31.49±3.82	26.71±0.23	33.91±3.42	29.86±0.22
Snap melon (Stressed)	28.62 ± 0.78	28.88±1.17	41.63±1.32	37.27±0.08	40.39±0.44	36.89±0.25

Table 7. Total phenol content in plants under different treatment

Treatment	Total Phenol (mgg ⁻¹ dry wt.)					
	Day of initiation of stress	Days after stress		Days after re-irrigation		
		05	10	5	10	15
Musk melon (Control)	2.68± 0.04	2.9±0.09	2.25±0.011	2.94±0.015	2.73±0.105	3.06±0.238
Musk melon (Stressed)	2.68 ± 0.04	2.45±0.03	1.303±0.028	2.36±0.06	2.66±0.34	2.413±0.049
Snap melon (control)	3.84 ± 0.06	3.37±0.04	3.52±0.055	3.97±0.061	3.16±0.091	3.42±0.175
Snap melon (Stressed)	3.84 ± 0.09	4.48±0.15	4.94±0.261	5.12±0.191	5.21±0.211	3.58±0.108

Drought stress has profound effect on physiological activities of the plants such as growth and developments, photosynthesis, transpirations, etc. (Vadell and Medrano, 1992). It has been demonstrated that initially the impact is observed at stomatal level where the stomatal aperture is reduced (Flexal and Medrano, 2002) subsequently leading to decrease in photosynthesis rate, due to reduction in CO₂ availability (Wong *et al.*, 1985; Cormic, 1994).

During present study a comparison was made between water stress tolerant (Snap melon) and susceptible (musk melon) plants for their response towards induced water stress. The results highlights that in musk melon plants the photosynthetic rate decreased with imposition of stress. The pattern parallels with transpiration rate also which shows that this crop species goes for reduction in stomatal aperture leading to reduction in photosynthetic rate. The results revealed that in musk melon drought response is at stomatal level as is also shown in other mesophytic plants (Wong *et al.*, 1995; Cornic, 1994; Reddy *et al.*, 2004 and Rouhi *et al.*, 2007). The data on carboxylation efficiency further demonstrate that a part of reduction in photosynthetic rate is also due to non-stomatal factor as has also been documented by Ramanjulu *et al.* (1998). The

carboxylation efficiency also decreases substantially with imposition of water stress.

In case of snap melon, the photosynthetic rate decreases slightly upto 5th day of water stress and to the tune of 21% by 10th day of drought stress. Similar pattern is also observed with respect to transpiration rate. The results revealed that in snap melon the stomatal aperture remains open even under receding soil moisture level permitting the free flow of CO₂ and its subsequent fixation. That such phenomenon takes place is further supported by the fact that upto 5th day of drought stress, the carboxylation efficiency is maintained.

Our results further demonstrates that recovery of photosynthetic rate is much faster in snap melon which is demonstrated by the fact that P_N rate was 19.88, 18.32 and 18.64 μmol CO₂ m⁻² S⁻¹ at 5th, 10th and 15th days of after re-irrigation which was better than in control plants. However in musk melon, the recovery in rate of photosynthesis is slow and remain lower than that observed on day of imposition of water stress as well as in control plants such pattern has also been observed by Romero *et al.* (2004) who also demonstrated that in almond during subsequent

recovery the photosynthetic rate is same or even better than that of control plants.

Yet another impact of drought on plants is that it induces oxidative stress in plants for which the plants develop a system of antioxidative defense. One such mechanism in plants employ compounds such as flavonoid, phenols, proline, ascorbate, etc. for neutralization of reactive oxygen species (Qureshi *et al.*, 2007; Weinder *et al.*, 2007 and Weinder *et al.*, 2009).

The comparative studies made by us on snap melon and musk melon turned out to be a model to access the effect of drought stress in these crop species. The data on flavonoid content in snap melon reveals that both under control and stress conditions, that quantity of flavonoid increases with age of plants, but the magnitude of increase is more under drought stress as compared to control. This demonstrates that flavonoid is accumulated under drought stress which may be acting as an agent to neutralize reactive oxygen. On the contrary, in musk melon the magnitude of flavonoid decreases showing thereby that they do not have potential to scavenge the additional reactive oxygen generated under drought stress. Similar results have also been shown with respect to phenols also where a marked increase in total phenols was recorded with imposition of drought stress (table 7). However, no change was observed in musk melon.

Thus, from the foregoing account it can be concluded that snap melon has stomatal as well as non-stomatal mechanism to maintain photosynthetic rate. They also have biomolecules to scavenge the additional reactive oxygen molecules developed under drought stress.

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Standardization of production technology for cucumber (*Cucumis sativus* L.) under protected environment

A. Parashar¹, P. K. Yadav¹, R. S. Singh² and A. K. Shukla³

¹Department of Horticulture, S K Rajasthan Agricultural University, Bikaner -334 006,

²ICAR-CIAH, Bikaner, ³ICAR-CAZRI, Regional Station, Pali

*Corresponding Author Email: avinashhorti@gmail.com

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Abstract

An experiment was conducted to standardize the production technology for cucumber (*Cucumis sativus* L.) under protected cultivation at Central Institute of Arid Horticulture, Bikaner during the year 2010-11. The experiment was laid out in Randomized Block Design with factorial concept comprised of three environments namely, glasshouse, polyhouse and net house and five varieties (Isatish, Hilton, Alamgir-CT-180, Poona Khira, Himangi) of cucumber. The results indicated a significant difference in all the vegetative growth parameters studied. The maximum vine length (3.01m), number of leaves (24.53), number of branches (1.75) and leaf area (448.37 cm²), respectively were found in glasshouse. Among different varieties of cucumber maximum vine length (3.26 m), number of leaves (29.96), number of branches (1.73) and leaf area (449.71 cm²) were recorded in variety Isatish. As far as effect of protected structure have a significant influence on photosynthetic rate ($\mu\text{m CO}_2/\text{m}^2/\text{s}$), transpiration rate ($\mu\text{m H}_2\text{O}/\text{m}^2/\text{s}$) and chlorophyll content (mg/g of fresh weight). The maximum photosynthetic rate (12.83 $\mu\text{m CO}_2/\text{m}^2/\text{s}$) and chlorophyll content (1.30 mg/g) were found in glasshouse. Maximum yield per hectare (84.06) recorded in cucumber crop raised under glasshouse condition. Among the varieties, maximum yield per hectare (86.78 t/ha) were recorded in variety Isatish, whereas, the minimum yield per hectare (59.01) was recorded in variety Himangi.

Key words: Cucumber, Zero energy polyhouse, Net house, Glasshouse, Cultivars, Parthenocarpic.

Introduction

Cucumber (*Cucumis sativus* L.) which belongs to family cucurbitaceae is one of the important vegetable crops from nutritional as well as economic point of view. It is a warm season vegetable grown throughout the country under tropical and sub-tropical conditions. It is said to be the native of Northern India (Pursglove, 1969). The fruit of cucumber is said to have cooling effect, prevent constipation, checks jaundice and indigestion (Nandkarni, 1927). Polyhouse cultivation is an emerging trend for growing vegetables in India. Production of cucumber in India is mainly restricted to its open field cultivation. It is mainly grown in summer and rainy season in Northern plains of India. Nevertheless, biotic and abiotic stresses are the main factors responsible for low yield and poor quality under open field cultivation. Summer season crop is mostly successful due to less incidence of diseases and pests, but rainy season crop is always affected by diseases and pests, resulting into low productivity and poor quality of fruits.

Singh *et al.*, (2005) suggested that Hasan and Sarig cultivars of cucumber are ideal for greenhouse cultivation during summer and rainy season, while Muhasun, Isatis, Dinar, Nun 9729, Nun 3019 and Kian can be grown successfully in winter season.

India, bestowed with a diverse and extreme agro-climatic conditions, has enormous potential for the protected vegetable cultivation technology, which can be utilized for the year round production of high value quality vegetable crops combined with high yield. Protected cultivation actually achieves higher water and nutrient use efficiencies. Increasing photosynthetic efficiency and reduction in transpiratory losses are added advantages of protected cultivation (Singh *et al.*, 2005). Both of these factors are of vital importance for healthy and luxuriant growth of crop plants. This technology is highly suitable for farmers in peri-urban areas of the country, especially in Northern plains of India. But protected cultivation requires careful planning and attention including selection of

varieties, suitable production technology like spacing, time of sowing and planting, water and nutrient management and plant protection to produce achieve yield of good quality. In view of importance of cucumber crop, the study was initiated to find out suitable the cultivar and suitable structures for cucumber cultivar under different type of green house structures.

Material and methods

The experiment was conducted at ICAR-Central Institute of Arid Horticulture, Bikaner, during the *kharif*, 2010. Bikaner is situated at 28.01°N latitude and 73.22°E longitude at an altitude of 234.70 meters above mean sea level. According to "Agro-ecological region map" brought out by the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) it falls under Agro-ecological region No. 2 (MgE1) under Arid ecosystem (Hot Arid Ecoregion with desert and Saline soil). The fertigation method was used to apply nitrogen, phosphorus and potassium in liquid form along with irrigation water as NPK was used 22 kg as per recommendation of the crop. For green house cultivation of cucumber, the seedlings were raised on soil-less media in plastic protrays having cells of 1.5" in size. The seedlings were ready for transplanting within 15-18 days. Three weeks old seedlings at 2-3 true leaf stage were transplanted at 60 cm x 60 cm according to the different treatment combinations.

The experiment was laid out in Randomized Block Design with factorial concept comprised of three environments namely, glasshouse, poly house and net house and five varieties (Isatish, Hilton, Alamgir-CT-180, Poona Khira, Himangi) of cucumber.

All the cultural practices including irrigation and hoeing were carried out, following the standard commercial procedures. Spraying for protection from pests and diseases were done whenever it appeared necessary throughout the growing season. Vines were vertically trained and maintained as single stems by the continuous pruning of all laterals.

The growth and physiological parameter were recorded from randomly selected five tagged plants of each treatment and further analyzed. All data were subjected to analysis of variance to determine main treatment effect and interactions.

Results and discussion

Vegetative growth characters

It is evident from the data (Table 1) that various types of structures and cultivars had significant effect on vegetative growth parameters of cucumber like, number of branches, average length of vine (m), average number of leaves and leaf area (cm²). As far as winter season was concerned various structures had significant influence on number of branches, average length of vine, average number of leaves and area of leaves. The maximum number

of branches per vine (1.75), average length of vine (3.01 m), and leaf area (448.37 cm²) were measured in glasshouse followed by polyhouse. Among the various vegetative growth parameter leaf area is an important variable for most of the physiological processes involving light interception for photosynthesis and potential evapotranspiration. Moreover, the rate of photosynthesis increased with the increase in carbon dioxide supply up to a certain extent. It is ubiquitous that vegetative growth is directly influenced by the photosynthetic activity (Pandey and Sinha, 2007). Light is also responsible for effecting the rate of photosynthesis in various ways. Few of ultraviolet light having shorter wave length apparently increased the photosynthetic rate (Pandey and Sinha, 2007). Temperature has little effect on the rate of the photosynthesis. However, very high and low temperature range affects the photosynthesis rate adversely. As the light intensity, carbon dioxide concentration and temperature inside the glasshouse was optimum for the growth and development of cucumber. Whereas, in case of polyhouse short wave radiation transmitted inside and long radiation transferred out. Thereby increased the inside temperature and resulted in lesser growth and yield as compared to glasshouse (Dwivedi and Dwivedi, 2005).

Similarly, Kwon and Chang (1996) reported that the length of the main stem before branching divergence was longest in chilli grown in glasshouse because of better environmental conditions. The glasshouse was the most favourable environment, as a result of a high transmittance of solar radiation, suitable temperatures for plant assimilation, and other environmental factors. However, appropriate cultivation techniques are also needed for the high yield to minimize the adverse effects of climate and soil.

Further, Table-1 showed that the maximum number of leaves (29.96), number of branches (1.75) and length of vine (3.26 cm) were recorded with variety Isatish however, leaf area (449.04 cm²) was observed with variety Hilton than the other variety. The significant difference in vegetative growth parameters, such as number of leaves, number of branches, leaf area (cm²) between cultivars may be due to varietal characteristic. Significant difference was observed among the cultivars for the vegetative growth characters by Al-Harbi *et al.* (1996) and Ramirez *et al.* (1988) in cucumber.

Flowering characters

Data clearly showed that the cultivars and different type of structures along with their interaction effects had significantly influenced the flowering characteristics as days to first flowering. Among the various protected structures, the least number of days to first flowering was recorded in glasshouse (37.60) followed by polyhouse (38.68). Favourable environmental conditions resulted in better vegetative growth and optimum photosynthesis. The

glasshouse resulted in more assimilation of photosynthates and accelerated the flower initiation. Further, in cucumber the flowers appear on every node of the vine; therefore, increased vine length resulted in more flowering and ultimately more fruit set. The similar results have also been reported by Kwon and Chang (1996).

Among the various cultivars, least number of days required for first flower initiation was recorded in cultivar Isatish (36.80) followed by Hilton (37.42). It has been reported that auxin can induce pistillate flower formation through its stimulation of ethylene production. An Auxin/IAA transcription factor was found to have higher expression in hermaphroditic flowers (Guo *et al.*, 2010). The findings of the present investigation are in close conformity with the findings of Gulam ud din *et al.* (2006) Guo *et al.* (2010) in cucumber and Kwon and Chang (1996) in chillies.

Physiological parameters

It is evident from the data presented in Table-1, the effect of structure have a significant influence on photosynthetic rate ($\mu\text{m CO}_2/\text{m}^2/\text{s}$), transpiration rate ($\mu\text{m H}_2\text{O}/\text{m}^2/\text{s}$) and chlorophyll content (mg/g of fresh weight). The maximum photosynthetic rate ($12.83 \mu\text{m CO}_2/\text{m}^2/\text{s}$) and chlorophyll content (1.30 mg/g) was found in glasshouse. Whereas, minimum transpiration rate ($1.02 \mu\text{m H}_2\text{O}/\text{m}^2/\text{s}$) was found in glasshouse. The photosynthetic rate, transpiration rate and chlorophyll content are dependent on different factors such as CO_2 concentration, temperature, light intensity, humidity, air temperature etc. Carbon makes up about 40 per cent of the dry matter, weight of higher plant, therefore, CO_2 concentration enrichment increased photosynthesis and plant productivity significantly. Increased CO_2 concentration in glasshouse (300-1000ppm) has been reported to increase photosynthesis and decreased stomatal conductance in most of the crop plant resulting in reduced transpiration rate per unit area of leaf and overall increase in water use efficiency (Dwivedi and Dwivedi, 2005). Reduced transpiration will alter the microclimate particularly, the selective humidity in immediate environment of plant which will have implication for other living organism sharing the same ecosystem with the plant.

Yield and yield attributing characters

Among the various yield attributing characters number of pickings (3.93), fruit length (13.52 cm), average fruit girth (3.50 cm), number of fruits per vine (20.37), weight of fruits per vine (3.52 kg), Average fruit weight (155.22 gm), yield/ m^2 ($8.41 \text{ kg}/\text{m}^2$) and fruit yield/ha (84.06 t/ha) were recorded maximum in glasshouse (Table-2). As higher chlorophyll content and maximum leaf area under glasshouse resulted in better vegetative growth, which ultimately envisaged the plants to enter into the reproductive phase. The length of vine was maximum under glasshouse, which resulted in flower bud formation on each node, better

fruit set, fruit development and fruit weight. In addition, microclimatic conditions in glasshouse was also favourable for plant growth characteristic as well as for yield parameters. Similar effects were observed by Sezen *et al.* (2010) and Champugain *et al.* (2004) in tomatoes.

Similarly, the early and total yield enhanced in pepper grown under glasshouse (Dasgum and Abak, 2003). It is a well known fact that the yield of vegetables under greenhouse condition depends on various factors such as variety, temperature, humidity, CO_2 concentration etc. Gucan *et al.* (2006) stated that the cucumber yield in unheated greenhouse was $8\text{-}10 \text{ kg}/\text{m}^2$ and $11\text{-}12 \text{ kg}/\text{m}^2$ in autumn and spring production period, respectively. The significant fruit length and fruit width in *Capsicum* was also reported in glasshouse (Pandey *et al.*, 2005). However, as the full season progressed, the average temperature was getting cooler and day length shorten which caused the fruit to take more days to attain a proper length (Kwon and Chan, 1996).

Among different cultivars the maximum number of pickings (5.13), average fruit length (14.57), fruit girth (4.17), number of fruits per vine (21.44), weight of fruits per vine (3.67 kg) and highest fruit weight (152.98 g) was obtained in cultivar Isatish. The significantly higher yield was recorded in cultivar Isatish ($8.68 \text{ kg}/\text{m}^2$) followed by Hilton ($7.78 \text{ kg}/\text{m}^2$). In gynocious varieties of cucumber under glasshouse condition resulted in higher level of auxin and lower level of ABA which ultimately favoured more fruit set and better development of fruit parthenocarpically. It has been reported that auxin can induce pistillate flower formation through its stimulation of ethylene production. (Guo *et al.*, 2010). The more fruit set per vine under glasshouse condition with more accumulation of food material in leaves and its transfer to developing fruits, which affected the fruit length and width and ultimately significant increase in fruit yield per plant and yield per square meter was observed as evident from the data (Chapagain *et al.*, 2004).

Fruit quality characters

The data presented in Table-3 revealed that the various cultivars had resulted in significant increase in vitamin C content (mg/100g), fiber content (%), calcium content (mg/100g), phosphorus content (mg/100g), iron content (mg/100g). Among different cultivars, the maximum vitamin C (6.37 mg/100g), phosphorus content (21.22 mg/100g), iron content (1.89 mg/100g) and the minimum fiber content (0.78 %) were found in cultivar isatish. However, calcium (15.00 mg/100g) was observed with variety Hilton than the other varieties. This might be due to genetic expression in the cucumber cultivars. The cucurbitaceae crop is known to be controlled by different genetic environment and hormonal factors. Fruit quality is also determined by the gene expression of a particular

variety under favourable climatic condition in greenhouse (Manzano *et al.*, 2008). Auxin induced pistillate flower formation through its stimulation of ethylene production; therefore, number of female flower were measured and it has been reported that the ethylene has higher genetic expression in case of gynocious line which could be a reason for improved performance of Isatish and Hilton variety under glasshouse. (Guo *et al.*, 2010).

Economics

The findings of the present studies reflected that the net returns were significantly affected by different types of structures. It is clear from the data that maximum net returns and B:C ratio can be obtained by the poly house structure with Rs. 35821/- per 500 m² and 2.18,

respectively. Whereas in case of cultivar, the maximum net return and B:C ratio was found with Isatish (Rs. 41049/- per 500 m² and 2.20, respectively). Similar economic results have been reported by Cantliff *et al.* (2008). Protected cultivation of vegetable offer distinct advances of quality, productivity and favorable market price to growers in adverse climatic conditions. Vegetable growers can substantially increase their income by protected cultivation of vegetables in off season production (Singh *et al.*, 2006).

The construction cost of glasshouse was high and there was no subsidy. Whereas, in case of poly house and net house there was subsidy of 70 per cent and initial investment was less compared to glasshouse. Therefore, the net returns under the glasshouse was on negative side.

Table 1. Effect of environments and varieties on yield and yield attributes

Environments	No. of leaves/ vine	No. of branches /vine	length of vine (cm)	Leaf area	Photosynthesis rate ($\mu\text{m CO}_2/\text{m}^2/\text{S}$)	Transpiration rate ($\mu\text{m H}_2\text{O}/\text{m}^2/\text{S}$)	Chlorophyll content (mg/g fresh weight)
Environments							
Poly house (P)	24.17	1.60	2.84	426.41	10.39	1.46	1.21
Net house (N)	23.04	1.32	2.71	404.15	8.58	1.57	1.11
Glass house (G)	24.53	1.75	3.01	448.37	12.83	1.02	1.30
C.D. (5%)	NS	0.09	2.84	27.31	2.37	0.21	0.09
Varieties							
Isatish (V ₁)	29.96	1.73	3.26	445.47	11.03	1.40	1.25
Hilton (V ₂)	25.40	1.60	3.13	449.04	11.04	1.38	1.26
Alamgir-ct-180 (V ₃)	22.02	1.47	2.80	414.67	10.34	1.33	1.18
Poona Khira (V ₄)	21.80	1.53	2.65	416.29	10.38	1.35	1.20
Himangi (V ₅)	20.40	1.44	2.43	405.76	10.21	1.31	1.15
C.D. (5%)	2.17	0.11	0.20	27.31	NS	NS	NS
Interaction							
PV ₁	31.13	1.80	3.26	443.20	9.91	1.40	1.26
PV ₂	25.33	1.73	3.12	449.53	10.92	1.80	1.27
PV ₃	21.27	1.47	2.68	415.60	10.10	1.38	1.19
PV ₄	22.00	1.60	2.63	416.60	7.92	1054	1.21
PV ₅	21.13	1.40	2.51	407.13	13.08	1.20	1.15
NV ₁	26.07	1.40	3.07	420.53	9.04	1.59	1.15
NV ₂	23.60	1.33	3.00	427.27	6.05	1.44	1.17
NV ₃	22.07	1.27	2.48	397.60	9.90	1.82	1.09
NV ₄	22.87	1.27	2.54	393.60	12.05	1.48	1.10
NV ₅	20.60	1.33	2.49	381.73	5.88	1.54	1.06
GV ₁	32.67	2.00	3.44	471.67	14.15	1.20	1.34
GV ₂	27.27	1.73	3.26	472.33	16.16	0.90	1.35
GV ₃	22.73	1.67	3.25	430.80	11.01	0.78	1.26
GV ₄	20.52	1.73	2.80	438.67	11.16	1.04	1.29
GV ₅	19.47	1.60	2.29	428.40	11.66	1.20	1.26
C.D. (5%)	NS	NS	0.34	NS	NS	NS	NS

Table 2. Effect of environments and varieties Vegetative and Physiological parameter

Treatments	Days to first flowering	No. of pickings	Average fruit length (cm)	Average fruit girth (cm)	Number of fruits/ vine	Weight of fruits / vine (kg)	Average fruit weight (gm)	Yield/m ² (gm)	Fruit yield (t/ha)	B:C ratio
Environments										
Poly house (P)	38.68	3.57	12.47	3.38	19.25	3.19	144.41	7.56	75.59	2.18
Net house (N)	39.83	3.31	11.89	3.22	17.32	2.49	121.32	5.67	56.72	2.01
Glass house (G)	37.60	3.93	13.52	3.50	20.37	3.52	155.22	8.41	84.06	0.95
C.D. (5%)	1.61	0.48	0.80	0.20	0.62	0.17	10.70	0.33	3.28	0.10
Varities										
Isatish (V ₁)	36.80	5.13	14.57	4.17	21.44	3.67	152.98	8.68	86.78	2.20
Hilton (V ₂)	37.42	4.80	13.89	4.05	19.40	3.33	150.56	7.78	77.82	1.98
Alamgir-ct-180 (V ₃)	40.62	2.96	11.98	3.02	17.96	2.87	135.22	6.62	66.20	1.43
Poona Khira (V ₄)	38.64	2.69	12.10	3.06	18.96	3.05	138.29	7.08	70.81	1.57
Himangi (V ₅)	40.02	2.44	10.60	2.53	17.16	2.42	124.54	5.90	59.01	1.40
C.D. (5%)	2.08	0.62	1.03	0.26	0.82	0.22	13.81	0.42	4.24	0.13
Interaction										
PV ₁	110.80	5.20	14.69	4.18	21.40	3.57	155.27	8.90	88.97	2.78
PV ₂	111.60	4.87	13.59	4.05	18.60	3.39	166.47	8.33	83.27	2.60
PV ₃	121.20	2.93	12.01	3.03	18.20	2.87	139.55	7.06	70.60	1.88
PV ₄	115.80	2.53	11.89	3.04	19.27	3.55	137.93	7.36	73.63	1.95
PV ₅	120.80	2.33	10.24	2.58	18.80	2.59	122.83	6.15	61.47	1.72
NV ₁	115.20	4.20	13.47	4.05	19.27	2.66	128.53	6.51	65.13	2.46
NV ₂	116.60	3.93	13.23	3.89	18.33	2.33	116.40	5.68	56.83	2.15
NV ₃	125.80	2.80	11.34	2.81	16.47	1.98	109.29	4.93	49.27	1.63
NV ₄	120.20	2.87	11.35	3.01	17.47	2.98	129.87	6.00	60.03	1.98
NV ₅	119.60	2.77	10.07	2.33	15.07	2.51	122.50	5.23	52.33	1.84
GV ₁	105.20	6.00	15.55	4.29	23.67	4.77	175.13	10.62	106.23	1.35
GV ₂	108.60	5.60	14.83	4.20	21.27	4.28	168.80	9.34	93.37	1.19
GV ₃	118.60	3.13	12.60	3.23	19.20	3.76	156.82	7.87	78.73	0.79
GV ₄	111.80	2.67	13.12	3.13	20.13	2.62	147.07	7.88	78.75	0.78
GV ₅	119.80	2.27	11.48	3.67	17.60	2.17	128.30	6.32	63.22	0.64
C.D. (5%)	NS	NS	NS	NS	1.42	0.38	NS	0.73	7.34	0.22

Table 3. Effect of environments and varieties on quality parameter

Treatments	Ascorbic acid (mg/100g)	Fiber content (%)	Calcium (mg/100g)	Phosphorus (mg/100g)	Iron (mg/100g)
Environments					
Poly house	5.76	0.98	13.68	19.64	1.64
Net house	5.50	0.97	13.48	19.24	1.62
Glass house	5.78	1.01	13.88	19.91	1.70
C.D. (5%)	NS	NS	NS	NS	NS
Varities					
ISATISH	6.37	0.78	14.67	21.22	1.89
HILTON	6.10	0.91	15.00	21.11	1.86
ALAMGIR-CT-180	5.47	1.24	12.09	18.13	1.41
POONA KHIRA	5.57	0.95	13.97	19.60	1.70
HIMANGI	4.90	1.04	12.67	17.91	1.42
C.D. (5%)	0.36	0.11	1.36	1.54	0.18

Interaction					
PV ₁	6.70	0.77	15.00	20.67	1.73
PV ₂	6.30	0.85	16.00	21.33	2.01
PV ₃	5.20	1.20	11.09	18.13	1.32
PV ₄	5.80	0.97	14.30	20.93	1.72
PV ₅	4.80	1.10	12.00	17.13	1.43
NV ₁	6.10	0.73	15.00	21.67	1.83
NV ₂	5.90	0.90	14.00	19.33	1.77
NV ₃	5.10	1.40	13.09	17.13	1.42
NV ₄	5.30	0.90	12.30	19.93	1.54
NV ₅	5.10	0.90	13.00	18.13	1.57
GV ₁	6.31	0.83	14.00	21.33	2.11
GV ₂	6.10	0.97	15.00	22.67	1.81
GV ₃	6.10	1.13	12.09	19.13	1.49
GV ₄	5.60	0.98	15.30	17.93	1.84
GV ₅	4.80	1.13	13.00	18.47	1.26
C.D. (5%)	NS	NS	NS	NS	NS

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Effect of different levels of NPK on yield and yield attributes of water melon (*Citrullus lanatus* Thunb.)

Mainu Hazarika, Deepa B. Phookan², Narayan Lal³ and Kavita Sinha¹
B N College of Agriculture, AAU, Biswanath Chariali, Assam-784176

¹Department of Hort, IGKV, Raipur, Chhattisgarh

²Department of Horticulture, AAU, Jorhat, Assam- 785013

³NRC Litchi, Muzaffarpur-842002, Bihar

*Corresponding author's email: narayanlal.lal7@gmail.com

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Abstract

An investigation was carried out to study the effect of different levels of NPK on fruit yield and yield attributes of watermelon. The treatments studied were T₁ (50 kg N, 35 kg P₂O₅, 50 kg K₂O), T₂ (60 kg N, 40 kg P₂O₅, 60 kg K₂O), T₃ (70 kg N, 45 kg P₂O₅, 70 kg K₂O), T₄ (80 kg N, 50 kg P₂O₅, 80 kg K₂O), T₅ (90 kg N, 55kg P₂O₅, 90 kg K₂O), T₆ (100 kg N, 60 kg P₂O₅, 100kg K₂O) and a control without fertilizer application (T₇) which were replicated three times. The result of the study revealed that the yield and yield attributing characters of watermelon were significantly affected by the different treatments tested. The treatment T₅ produced significantly the highest 35.77 t/ha fruit yield while control plant produced the lowest fruit yield 8.64 t/ha and also it was superior over other treatments in term of number of female flower/vine (14.50), fruit diameter (22.49 cm), Flesh thickness (19.75 cm), Flesh to rind ratio (2.99), Fruit dry weight (1144.80 g) /vine, Biological yield (1638.30g), Harvest Index (69.88%) and total sugar content of the fruit (7.62 %). Therefore, the T₅ with 90:55:90 kg NPK /ha could be suggested as the optimum fertilizer dose for maximizing yield and its attributes of watermelon variety sugar Baby for agro-climatic condition of Assam.

Key words: Fertilizer dose, Yield, Harvest Index, Flesh to Rind ratio, Watermelon

Introduction

Watermelon (*Citrullus lanatus* L.) is a member of the family cucurbitaceae, kingdom : plantae, order : cucurbitales, Genus : citrullus and species : lanatus (Wikipedia, 2013). It refers to both fruit and plant of vine like (Climber or trailer) herb (Thulaja, 2005). Watermelons are rich in water and as such are helpful in preventing dehydration. The low calorie content of the fruits makes it a best choice for diet conscious people (Sonia, 2013). The seeds are rich in fat and protein and are eaten as snacks added to other dishes or used as oil seed. The rind of watermelon is often pickled and the fruits are cooked as a vegetable when immature while the mature fruit when flesh turn red is eaten in raw (Maitra, 2007). The crop growth and yield performance of watermelon is influenced by a number of factors like soil, climate, manures & fertilizers, irrigation, control of pests, diseases, weeds etc of which the application of fertilizers under intensive system of cultivation is identified as the single most important factor controlling the yield optimization. Since farm yard manure or compost alone cannot suffice the entire nutrient requirement of the crop to maintain adequate growth

performance through out the life cycle which is otherwise the key requirement for a profitable farming system, hence the plants often suffer from hidden hunger of major plant nutrients like nitrogen, phosphorus and potash. As such direct application of nitrogen, phosphorus and potash appears to be the prime requirement for maximizing plant growth rate and there by to increase the biological yield so as to hold maximum economic yield with better fruit quality. The doze, time and method of NPK fertilizer application must be optimum to make it as profitable venture under the prevailing agro-climatic condition of this region of the country where the watermelon might appear as one of the most important fruit vegetable crop of the summer season. However, at present the crop is cultivated in meager areas mainly because of lack of the proper cultivation practices of the crop suitable for this region. Therefore, the present study was undertaken to find out the most suitable combination of NPK for the agro-climatic condition of Assam for watermelon (*Citrullus lanatus* Thunb.) so that the grower can harvest the maximum yield with better fruit quality.

Materials and methods

The investigation was conducted during 2009-10 in the Experimental Orchard, Department of Horticulture, Assam Agricultural University, Jorhat, Assam. The soil of the plots was sandy loam with p^H 6.5 and available soil nitrogen, phosphorus and potassium were 295.00, 40.82 and 114.05 kg/ha, respectively. The experiment comprising seven treatments was laid out in Randomized Block Design with three replications. The plot size of 6m X 4m were prepared and seeds of watermelon variety *Sugar baby* were sown in the month of February at a spacing of 2m X 2m accommodating 6 plants in each plot. Different fertilizer treatments were applied as basal as well as 30 days after sowing as per different treatment combinations. The seven different treatments tested were T_1 (50,35,50 : NPK kg/ha), T_2 (60,40,60 : NPK kg/ha), T_3 (70,45,70 : NPK kg/ha), T_4 (80,50,80 : NPK kg/ha), T_5 (90,55,90 : NPK kg/ha), T_6 (100,60,100 : NPK kg/ha) and T_7 (control). Fifty percent of nitrogen in the form of urea, full dose of phosphorus in the form of single super phosphate and full dose of potassium in the form of muriate of potash were applied as per the treatment at the time of sowing which were then mixed and covered with soil. The remaining 50 % of nitrogen was applied in soil at 30 days after sowing. All other recommended package of practices was followed. The data in respect to crop growth, yield attributing characters and quality of fruit were recorded which were then statistically analyzed for the test of significance following the method of Ponce and Sukhatme (1995).

Results and Discussion

The Table-1 revealed a gradual increase in the number of days required to first harvest the watermelon fruits with the increase in fertilizer doses and treatment T_6 plants with highest fertilizer dose took the significantly longest 91.65 days period as compared to control plants which needed the shortest 86.00 days period for the same. All other treatment took the period in between these two extreme, however failed to differ significantly from control. The higher dose of nutrient specially the nitrogen might help the plant to continue vegetative growth for longer period by altering the C: N ratio and delayed the reproductive phase and harvesting maturity of fruits. Similar findings were also reported by Kumar *et al.* (2003) & Pandey *et al.* (1996) in different vegetable crops from different parts of the world.

The male flower number per vine of watermelon significantly differed in different treatment combinations and the highest 154.33 male flower number per vine was recorded in T_3 which was at par with T_5 (152.11) while the control plants produced the significantly lowest 120.45 male flower number per vine. Similarly, Table-1 showed a significant variation of female flower number per vine of watermelon under different treatments. The T_5 plants recorded the significantly highest 14.50 female flower

number per vine which was at par with T_6 (13.65), in contrast the control plants maintained the significantly lowest 8.55 female flower number per vine. In general an increasing trend of both male and female flower number per vine of watermelon was observed with the increase in fertilizer dose. This might be due to the principle that higher fertilizer doses cause more vegetative growth thereby accumulate more reserve food materials and alter C:N ratio which in turn may produce more flower particularly the female flower per vine lowering the male : female flower ratio of watermelon. A balanced nutrition is utmost necessary to maintain vigorous vegetative growth at the early stage so as to build up sufficient food materials within the plant before entering into reproductive phase and in later phase the maintenance of a proper sex ratio with higher female flower number per vine of cucurbits like watermelon is equally important to get higher fruit number per vine and total fruit yield per hectare. This finding is in close agreement with Olaniyi (2008), Hazarika *et al.* (2012), Efediyi and Samson (2009) who reported similar observations from different part of the globe in muskmelon, watermelon and cucumber.

The diameter of individual watermelon fruit was significantly affected by the present treatments and the significantly highest 22.49 cm fruit diameter was recorded in T_5 which was at par with T_6 (22.42 cm) and both were significantly superior over all other nutrient treatments (Table-1). On the other hand control plants produced the smallest fruits with 13.92 cm fruit diameter followed by T_1 with 14.93 cm diameter and they were statistically at par but significantly inferior than all other treatments. A similar trend was observed in case of flesh thickness of the fruit and the highest 19.75 cm flesh thickness was recorded in T_5 which was at par with T_6 with 19.74 cm flesh thickness while significantly lowest 10.33cm flesh thickness was recorded in control fruits. In contrast the control fruits maintained the significantly thickest 1.80 cm rind thickness followed by T_1 (1.66 cm) and T_2 (1.65 cm) and they were statistically at par but the control plants differed significantly from other treatments while T_6 plant had the smallest 1.37 cm rind thickness followed by T_5 (1.37 cm) and T_4 (1.50 cm). Due to thicker flesh and thinner rind composition the T_5 fruits were able to hold the highest flesh to rind ratio of 2.99 followed by T_6 (2.98) which were at par but significantly superior than all other treatments. The control fruits for the same reason could result the lowest ratio of 1.48 and other treatments were able to maintain significant superiority in this regard over control fruits (Table-1). The highest fruit diameter (22.49 cm), flesh thickness (19.75 cm), flesh to rind ratio (2.99) were recorded in T_5 with higher fertilizer level which may be attributed to higher photosynthetic activity for prolong period and better capacity for dry matter partitioning and assimilation of the treated plants and thereby increased the

fruit diameter, flesh thickness, flesh to rind ratio and decreased rind thickness compared to control plants. Similar results were also observed by Oloyede *et al.* (2013) in pumpkin. The result of the present study also revealed that the dry fruit yield per vine, fruit yield per hectare, vine dry weight, biological yield as well as harvest index of watermelon were significantly affected by the different fertilizer doses tested. The highest 1144.80 g dry fruit yield per vine, 35.77 t/ha fruit yield, 1638.30 g biological yield and 69.88 % harvest index were recorded in the treatment T₅ again these were the minimum in case of control except the harvest index which was minimum 57.65% in T₁. The higher fruit yield of watermelon in elevated fertilization might be due to larger size and weight of the individual fruit which in turn increased the dry yield per vine. These increased individual fruit size and fruit weight per vine in elevated fertilizers might be attributed to the ability of NPK to promote vigorous vegetative growth at initial and then final reproductive growth of watermelon by instantly supplying the necessary raw materials required for formation and development of new cells and tissues and by favouring other physiological activities relating to mobilization of more food materials to economic parts to increase harvest index. The role of fertilizer in increasing the plant vigour in the form of length and weight of vine and number and size of leaves, leaf area index, leaf chlorophyll content were well documented in many crops and these increased leaf area might carry out more photosynthesis and converted light

energy to chemical energy more efficiently and thus accumulated more biomass for subsequent reproductive growth. Similar results were also observed by Olaniyi and tell (2011), Olaniyi (2000 & 2006) and Sabo *et al.* (2013) in watermelon.

The juice content of the fruit and total sugar content of the juice were also significantly affected by different treatments (Fig-1 & Fig-2). The T₅ maintained statistically significant superiority over all other treatment in these two fruit quality parameters whereas control fruits were the least performer. This might be the fact that balanced nutrition not only increase the crop growth and yield of watermelon (Hazarika *et al.* 2012) but also improve the soil physical and chemical properties (John *et al.*, 2004), thereby help the plant to sustain vigorous vegetative for prolonged period and boost up the reserved food and timely mobilize to the reproductive parts leading to more yield with better fruit quality. The positive correlation of NPK fertilization with the increasing fruit quality has also been reported by Okur & Yagmur (2004) and Hazarika *et al.* (2012) in watermelon. The present study therefore revealed that a balance fertilizer application is the utmost necessity to increase the production and productivity of watermelon as such T₅ with 90-55-90: NPK kg ha⁻¹ could be suggested as the best fertilizer treatment combination for watermelon in agro climatic condition of Assam to harvest the highest fruit yield with better quality which is necessary for commercial farming.

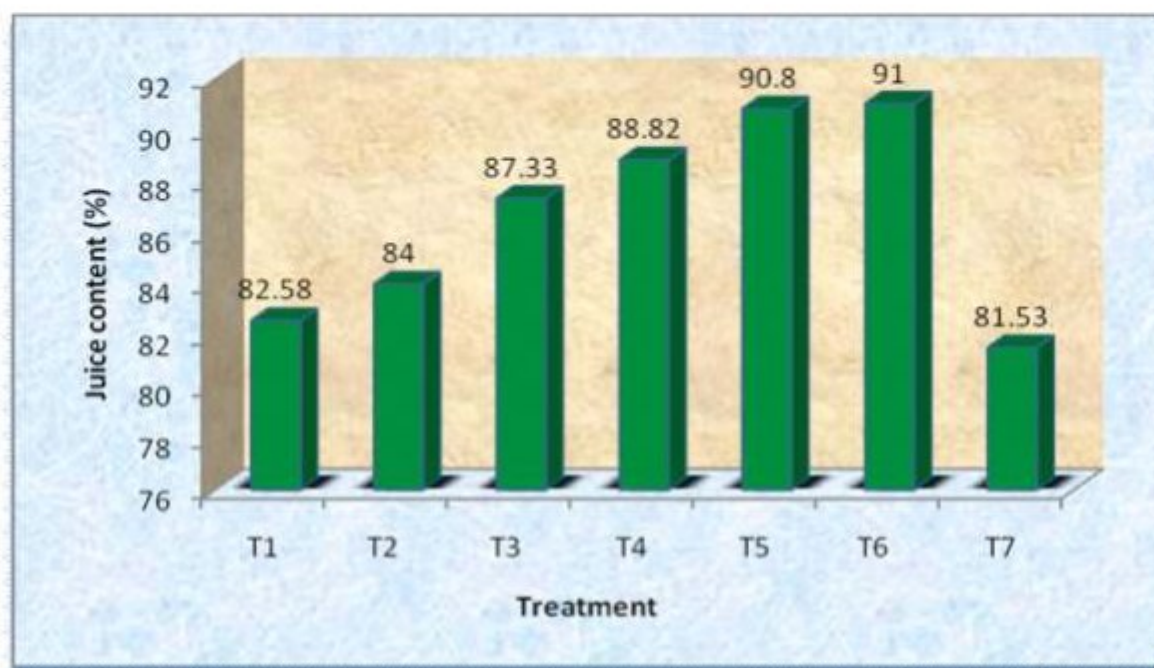


Fig 1 : Effect of different levels of NPK on Juice Content of watermelon

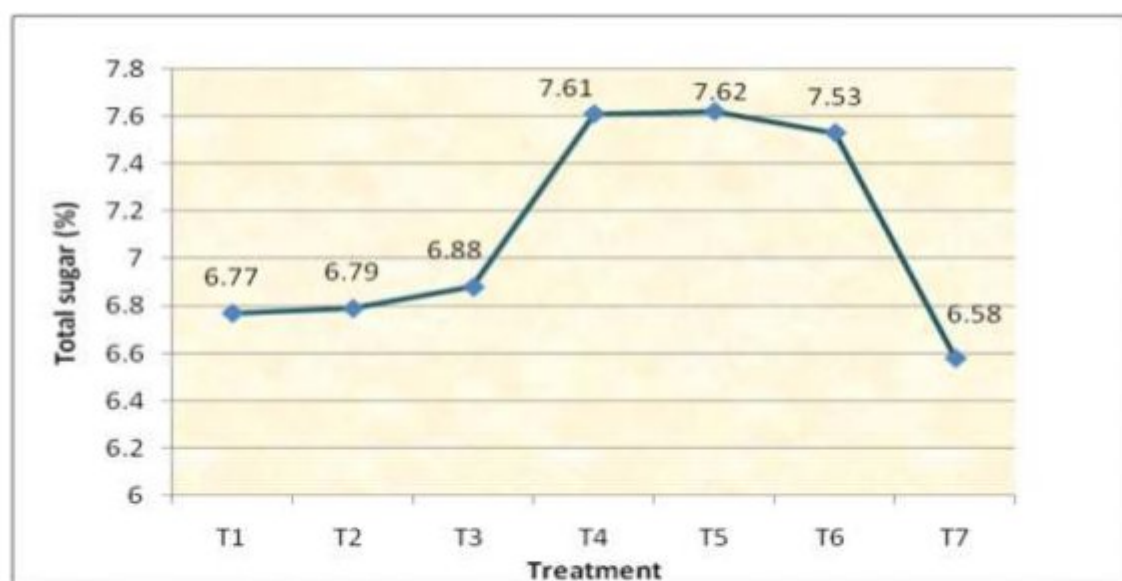


Fig 2 : Effect of different levels of NPK on Total Sugar content of watermelon

Table-1. Effect of N, P and K on yield and yield attributes of watermelon

Treatments	Days to first harvest	No. of male flower/vine	No. of female flower/vine	Fruit diameter (cm)	Flesh thickness (cm)	Rind thickness (cm)	Flesh to rind ratio	Fruit dry weight /vine (g)	Vine dry weight (g)	Biological Yield (g)	Fruit Yield (t/ha)	Harvest Index (%)
T ₁	87.00	136.55	11.26	14.93	11.68	1.66	1.77	344.80	253.28	598.08	10.78	57.65
T ₂	87.52	147.25	11.50	16.05	12.75	1.65	1.93	393.60	336.38	729.98	12.30	53.92
T ₃	87.60	154.33	12.60	19.91	16.77	1.57	2.53	637.60	346.72	984.32	19.93	64.78
T ₄	88.24	147.00	12.51	21.16	18.16	1.50	2.74	788.00	480.31	1268.31	24.63	62.13
T ₅	88.70	152.11	14.50	22.49	19.75	1.37	2.99	1144.80	493.50	1638.30	35.77	69.88
T ₆	91.65	147.20	13.65	22.42	19.74	1.34	2.98	1067.20	493.52	1560.70	33.35	68.39
T ₇	86.00	120.45	8.55	13.92	10.33	1.80	1.48	276.80	180.18	456.98	8.64	60.57
S.Ed±	1.31	1.10	0.41	0.48	0.56	0.08	0.09	10.60	4.86	15.46	2.66	1.32
C.D (5%)	2.85	2.40	0.90	1.04	1.21	0.18	0.19	23.20	10.58	33.78	5.79	2.85

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Effect of drip irrigation levels and fertigation on capsicum cultivars under protected cultivation

I. M. Verma, S. R. Bhunia and Mohd. Arif

College of Agriculture, S K Rajasthan Agricultural University, Bikaner- 334 006

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Abstract

An experiment was conducted during 2010-11 and 2011-12 in poly-house at Niche Area Excellence Farm, Bikaner to study the effect of drip irrigation and fertigation levels on plant height, fruit yield, and water use efficiency of capsicum. The treatments consists of three drip irrigation schedules viz. 40, 60 and 80% ETc and three fertigation levels viz. 75%, 100% and 125% of recommended dose of fertilizers. The experiment was conducted in randomized block design and replicated thrice. The study indicated that there was increase in plant height, fruits /plant and fruit yield with increase in irrigation levels from 40% to 80% ETc, but the water use efficiency decreases with increasing irrigation levels. The study further indicated that plant height, fruits /plant, fruit yield and water use efficiency also increased with increasing the fertigation levels from 75% to 125% recommended dose of fertilizer.

Key words: Fertigation, drip irrigation level, capsicum, water use efficiency.

Introduction

Rajasthan, particularly western region comes under hyper arid zone with very scarce water resource, scanty and erratic rainfall. The arid climate is quite extreme with temperature as high as near about 49°C in summer and as low as 0°C in winter. Thus, adoption of protected cultivation may prove useful for improving farm income and it is an effective tool for higher and quality production. Capsicum grown in the naturally ventilated polyhouse showed four times more yield and yield component compared to those grown in the field (Nagalakshmi et al., 2001). Drip irrigation maintains moisture content at near about field capacity in one hand and eliminates water losses on other hand. Fertigation with drip irrigation also enhance the water use efficiency as compare to sole application of fertilizers. Drip irrigation along in conjunction of fertigation increase fruit yield of capsicum by about 40% over control inside the polyhouse (Singh et al., 2010). Overall growth in terms of height of plant numbers of leaves per plant inside the green house was more compared to open field (Ghosal and Das, 2012). Capsicum is a long duration crop but early flowering and fruiting observed in greenhouse condition (Ghosal and Das, 2012). Production of vegetables under protected cultivation system results in effective use of the land resources, beside being able to increase the production of quality vegetables for both the export and domestic markets by offsetting biotic and abiotic stresses to a great extent that otherwise prevalent in open. Cultivation of capsicum in a polyhouse was found to be highly feasible as

reflected in higher values of net present value (NPV), B:C ratio and internal rate of return with payback period of less than two years (Murthy et al., 2009).

Materials and methods

An experiment was conducted during 2010-11 and 2011-12 in poly-house at Niche area excellence farm, S K Rajasthan Agricultural University, Bikaner situated in arid western hyper arid zone of Rajasthan. The soil was sandy loam in nature, having field capacity 6.6%, PWP 1.9%, bulk density 1.52 g/cc, pH (1:2) 8.3, electrical conductivity (1:2) 0.15 dS/m. The soil is very low in organic matter (0.10%) and medium in available P (33 kg/ ha) and high in available K (350 kg/ ha). The experiment was laid out in randomized block design with three replications. The treatments consist of three irrigation levels (40%, 60% and 80% ETc) and three fertigation levels (75%, 100% and 125%). The total irrigation water provided was 489.62, 655.54 and 979.26 mm at 40%, 60% and 80% ETc, respectively (Table 1). Ground water was below 10 m throughout the growth period. Capsicum variety Indra was sown at 30 cm plant to plant and 60 cm row to row spacing on October 15, and capsicum fruits were harvested 13 times from December 10 to July 15-18 under protected cultivation in both the years. Under ambient condition fruits were harvested 5 times at 15 days interval during December 10 to February 20, in both the years. All the cultural operations were carried out as per recommendations.

Results and discussions

Irrigation levels

Increasing irrigation levels from 40% to 80% ETc under drip system increased plant height, fruit/ plant and fruit yield (Table 2). Increased plant height and yield attributes with increasing irrigation levels through drip irrigation thus, enhanced fruit yield of capsicum and highest fruit yield of 814 q /ha was recorded at 80% ETc against 655 and 251 q /ha with irrigation at 60%, 40% ETc through drip and surface irrigation, respectively. The above observation revealed that all drip irrigation levels under protected cultivation gave significantly higher fruit yield of capsicum than surface irrigation at open field condition (251 q/ha). This is in confirmatory with Nagalakshami et al., 2001, who reported that capsicum grown in naturally ventilated poly house showed four times more yield and yield component compared to those grown in the field.

Capsicum being a long duration crop under protected cultivation used more water than the crop grown in open field condition. Highest amount of water use (979.26 mm) was recorded with 80% ETc followed by 655.54 and 575.25 mm with 60% ETc under protected cultivation and surface irrigation under open field condition, respectively. Increased water use in protected cultivation decreased water use efficiency. Thus, crop grown with 40% ETc in polyhouse gave the highest water use efficiency (133.77 kg/ ha-mm) against 112.88 and 83.12 kg/ ha-mm with 60 and 80% ETc, respectively under protected

cultivation. Lowest water use efficiency of 43.45 kg/ha-mm was recorded with surface irrigation under open field condition. Lower water use efficiency in surface irrigation (absolute control) may be due to loss of irrigation water from sandy loam soil through deep percolation resulted in higher water use and low fruit yield as the crop was exposed to natural adverse climate.

Fertigation

The study of three fertigation levels indicated that plant height, fruit per plant, fruit yield and water use efficiency increased with increasing the fertigation level from 75% to 125% recommended dose of fertilizer. However fruit per plant were not significantly influenced by higher dose of fertilizers and it was statistically at par with 100% and 125% recommended dose of fertilizer. The highest fruit yield 797 q/ha was recorded at 125% recommended dose against 740 and 672 q/ha at 100% and 75% recommended dose, respectively (Table 2).

The water use in 75% to 125% recommended dose of fertilizers was same but the water use efficiency increased with increasing the fertigation level from 75% to 125% of recommended dose of fertilizer. The highest water use efficiency of 112.54 kg/ha-mm was recorded at 125% of recommended dose as against 104.45 and 94.90 kg/ha-mm at 100% and 75% of recommended dose of fertilizer, respectively.

Table 1 : Month-wise irrigation events and irrigation water applied (mm) under polyhouse (mean of two years)

Month	Irrigation events	Drip irrigation (mm)		
		40% ETc	60% ETc	80% ETc
October (15-31)	8	19.09	25.39	38.18
November	15	40.79	54.25	81.59
December	15	36.57	49.01	73.15
January	16	36.58	49.02	73.17
February	14	27.14	36.36	54.27
March	15	57.68	77.29	115.36
April	16	78.00	104.52	156.00
May	15	103.63	138.87	207.27
June	16	81.74	109.53	163.47
July (1-7)	3	8.40	11.30	16.80
Total	133	489.62	655.54	979.26

Table 2: Effect of drip irrigation and fertigation on height, yield attributes and yield of capsicum under protected cultivation (pooled of two years)

Treatment	Plant height at harvest (m)	Fruit/ plant	Fruit yield (q/ha)	Water use (mm)	Water use efficiency (kg/ha-mm)
Irrigation level					
40% ETc	3.09	12.1	655	489.62	133.77
60% ETc	3.75	15.8	740	655.54	112.88

80% ETc	3.88	15.9	814	979.26	83.12
Control (Surface irrigation)	1.32	7.4	251	575.25	43.45
SEm±	0.06	0.3	5		
CD at 5%	0.18	0.9	14		
Fertigation					
75% RD	3.05	13.7	672	708.14	94.90
100% RD	3.69	14.8	740	708.14	104.45
125% RD	3.98	15.3	797	708.14	112.54
SEm±	0.06	0.3	5	-	-
CD at 5%	0.18	0.9	14	-	-

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Response of vermicompost and nitrogen on growth, yield and quality of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]

Karshan Kumar^{1*}, P.K. Yadav², Om Prakash Rolaniya³ and Desh Raj Choudhary⁴

Department of Horticulture, College of Agriculture, SKRAU, Bikaner
Division of Vegetable Science and Floriculture, SKUAST, Jammu (J&K)

*Corresponding author e-mail: Jandu0002@gmail.com

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Abstract

In the present investigation, the response of bottle gourd to different levels of vermicompost (control, 3, 6 and 9 tones ha⁻¹) and nitrogen (control, 50, 75 and 100 kg ha⁻¹) was studied at SKRAU, Bikaner during summer season of 2016. The vermicompost applied at the rate of 6 tones ha⁻¹ has shown least number of days for appearance of first female flower, while number of primary branches per vine, length of leaf (cm), per cent fruit set, fruit length, weight and total yield per vine etc. were found maximum in plants applied with 9 tones ha⁻¹. The application of increasing levels of nitrogen 100 kg ha⁻¹ has significantly increased the length of leaf, per cent fruit set, number of fruits per vine, fruit length, weight and total yield per vine etc., chlorophyll content in plant (mg/100), P uptake by plant and available N content in soil after harvesting compared to the control. The treatment combination of vermicompost (9 t ha⁻¹) + nitrogen (100 kg ha⁻¹) has showed maximum number of primary branches per vine, leaf length (cm), per cent fruit set, number of fruits per vine etc. compared to the control plants. The maximum yield (q ha⁻¹) was found under the treatment combination of vermicompost (9 t ha⁻¹) + nitrogen (100 kg ha⁻¹) while remaining treatment combinations was at par with each other. The higher nitrogen content as well as B: C ratio (1.70) in plant was observed in the treatment combination of vermicompost (6 t ha⁻¹) + nitrogen (100 kg ha⁻¹).

Key words: Bottle gourd, Vermicompost, Nitrogen, Growth, Yield, Quality

Introduction

Bottle gourd (*Lagenaria siceraria* (Mol.) Standl.) is one of the most important vegetable crop belonging to family cucurbitaceae. It is cultivated in spring, summer and rainy season throughout India. The major growing states in India are Uttar Pradesh, Punjab, Gujarat, Assam, Tamil Nadu and Rajasthan. The mature fruit contains minerals (30.7mg), protein (0.29g), carbohydrate (2.5g), vitamins (0.51mg) and about 96.1 per cent moisture per 100 g fresh edible portion (Gopalan et al., 1982). Besides culinary purpose, it is also used for preparations of different type of sweets, rayta and halwa. Dried fruit shells are used for making musical instruments, utensils and floats for fishing nets (Chadha, 2001). It has wide medicinal value as laxative, digestive and to prevent constipation. Poultice prepared from fruits is used in wounds, fruit ash mixed with honey used to cure headache, sugar mixed leaves can be given to jaundice patients (Singh and Joshi, 2002).

Vermicompost is an organic fertilizer enriched with all beneficial soil microbes and also contains all the essential plant nutrients. It contains about 2.5 per cent N, 1.5

per cent P₂O₅ and 1.5 per cent K₂O and also rich in micronutrients such as Mg (0.46%), Fe (7563 ppm), Zn (278 ppm), Mn (475 ppm), Bo (34 ppm), Cu (27 ppm) (Gupta, 2003). It is non-toxic; utilize low energy input for composting and recycled bio-organic product. It is eco-friendly and has beneficial effect on the biochemical activities of the soil (Ali and Jahan, 2001). It also enhances soil aeration, texture, tilth and quality, fertility and mineral content of the soil. It improves water holding capacity of soil because of its high organic matter content and promotes better root growth and nutrient absorption (Nourbakhsh, 2007).

Nitrogen is one of the most important nutrients for crop growth, second only to water. Nitrogen exists in many different chemical forms and passes around natural and agricultural ecosystems in a cycle. It is one of the main chemical elements required for plant growth and reproduction. It is a component of chlorophyll and therefore essential for photosynthesis. It is also the basic element of plant proteins, including the genetic material DNA, RNA, amino acid and vitamins is important in periods of rapid

vegetable growth. It also play an important role in plant metabolism by virtue of being an essential constituent of diverse type of metabolically active compounds like amino acids, proteins, nucleic acids, prophytins, flavins, purine, pyrimidine, nucleotide, flavin nucleotides, enzymes, co-enzymes and alkaloid.

Materials and Methods

The present study was conducted experiment farm, SKRAU, Bikaner situated at an elevation of 234.7 meters above mean sea level on latitude of 28°01' N and longitude of 73°22' E during summer season 2016. The experiment was laid out in factorial randomized block design (RBD) with three replications comprising of sixteen treatment combination of four levels of vermicompost (control, 3, 6 and 9 tonnes ha⁻¹) and four levels of nitrogen (control, 50, 75 and 100 kg ha⁻¹). The seeds were soaked in cold water overnight before sowing for better germination and sown in the rows keeping 2.0 m inter-row spacing and plant to plant distance of 0.50 m at a depth of 1.5 to 2.0 cm. Fertilization, other cultural practices and need based plant protection measures were followed as recommended for commercial production. The whole quantity of vermicompost was uniformly spread at the time of bed preparation in the soil. The required quantity of urea as per nitrogen treatments was supplied in three splits *i.e.* one-third at the time of sowing and remaining quantity in two splits. The first dose of urea was top dressed 30 days after sowing and remaining dose at 60 days after sowing.

The data were recorded on five randomly selected plants from each replication for days to appearance of first female flower, node at which first female flower appeared, Number of primary branches per vine, per cent fruit set, number of fruit per vine, weight of fruit, total yield per vine, total yield (q/ha). Length and width of leaf (cm) at 60 days after sowing, length of fruits and length of main vine (m) at harvest was measured with the help of measuring tape. Girth of fruits was measured with the help of vernier calliper. The Crude fiber content in fruit (per cent) was estimated the method of (AOAC, 1960). Chlorophyll content in plant (mg/100g) was estimated by method of Hiscox and Israelstom (1979). The NPK content in plant estimation were done by colorimetric method (Snell and Snell, 1939), vanadomolybdo phosphate yellow colour method, flame photometric method respectively. NPK uptake by plant was calculated from nitrogen, phosphorus and potassium content in fruit and yield of fruit. Available of NPK in soil after harvesting was determined by alkaline Permanganate method (Subbiah and Asija 1956) and available P₂O₅ in the soil was estimated by Olsen's method (Olsen *et al.* 1954). The available potassium was determined by flame photometer method. The recorded data were averaged and statistically analysed (Steel and Torrie, 1981) using the statistical programme developed by O.P. Sheoran.

Results and Discussion

The effect of four levels of vermicompost and nitrogen was studied to understand the growth, yield and quality of bottle gourd. The results obtained are presented in Table 1, 2 & 3 for individual effect and interaction, respectively.

Effect of vermicompost

Among four levels of vermicompost studied, varied differences in all the growth traits were found to be statistically significant (Table 1 & 2). Periodical growth rate revealed that the levels of vermicompost 6 t ha⁻¹ vermicompost in less days taken to appearance of first female flower (58.91) than the control (60.65). Node number at which first female flower appeared earlier in 9 t ha⁻¹ vermicompost (11.52), was at par with 6 t ha⁻¹. Maximum number of primary branch/vine at harvest was recorded in 9 t ha⁻¹ vermicompost (10.99) and leaf length at 60 days after sowing (27.43 cm) than the control (7.82 and 19.52 cm), respectively. Maximum length of main vine was recorded in 9 t ha⁻¹ vermicompost (3.99 m) which at par with 6 t ha⁻¹ (3.94 m) as compared to control (2.84m). Maximum leaf width (26.19 cm) was observed in 9 t ha⁻¹ vermicompost but not any significantly difference with 6 t ha⁻¹ (25.87 cm) than the control (18.64). Improvement in plant growth attributes with the application of vermicompost might be due to better not only provided plant nutrients but also improve the physical condition of the soil in respect of granulation, friability, porosity which intern provided a balance nutritional environment favorable both soil rhizosphere and plant system. Similar results have been reported by Kaur *et al.*, 2015.

Out of the four application of vermicompost (Table 1 & 3) maximum per cent fruit set (52.16), number of fruit per vine (9.46), fruit length (37.74 cm), fruit girth (22.83 cm), fruit weight (874.43g) and total yield per vine (8.91 kg) were observed in 9 t ha⁻¹ vermicompost as compared to control and highest total yield (249.75 t/ha) in 9 t ha⁻¹ vermicompost which was statistically at par with 6 t ha⁻¹ (245.57) as compared to control. The significant improvement in yield account of vermicompost along with nutrients from soil particularly at later stage of crop growth might have encases the rate of photosynthesis with further increased vegetative growth and provided more site for translocation of photosynthesizes with ultimately increased the yield. Similar results have been obtained by Coulibaly *et al.*, (2016).

Vermicompost had non-significant effect (Table 3) on the crude fiber content in fruit however; maximum crude fiber was recorded in 9 t ha⁻¹ (1.39%). Maximum chlorophyll content (49.54mg/100g) was observed in 9 t/ha and minimum in control. More N content in plant (0.0432), N and P uptake by plant was observed in 9 t/ha vermicompost than the other treatments. Available of NPK

in soil after harvesting (99.28, 36.35 and 357.34) was significantly increase with increases the levels of vermicompost 9 t ha⁻¹ was superior over control. The increasing photosynthetic efficiency resulting in more dry matter production and nutrient concentration in plant seems to be major factor responsible for higher NPK uptake to plant root zoon under higher application of vermicompost 9 t ha⁻¹. Similar findings have been reported by Thirunavukkarasu and Balaji (2015).

Effect of nitrogen

The results of application of 100 kg nitrogen was helpful in increasing vegetative growth (Table 1 & 2). The beneficial effect of higher level of nitrogen in increasing the growth in terms of node number at which first female flower appeared earlier in 100 kg ha⁻¹ (11.49), was at par with 75 kg ha⁻¹ (11.72) than the control. Maximum length of main vine (4.11m) was observed in 100 kg N ha⁻¹ which at par with 75kg N ha⁻¹ (4.06 m). Number of primary branch per vine at harvest and (11.32)and leaf length (28.25 cm) significant higher were recorded in 100 kg ha⁻¹ than the control. Maximum width of leaf (26.93 cm) was recorded under 100 kg ha⁻¹, followed by 75 kg ha⁻¹ (26.68 cm) than the control. Nitrogen might be due to better nutritional availability in the root zone as well as in the plant system. It also plays an important role in proper growth and development of plants by virtue of being an essential constituent of diverse type of metabolically active. The results reported by Arshad *et al*, (2014) is in line with present findings.

The might have (Table 1 & 2) increased the yield attributes significantly higher by increasing the sink size in terms of per cent fruit set (53.73 per cent), number of fruit per vine (9.71), length of fruit (38.88 cm), weight of fruit (913.23 g), total yield per vine (9.30 kg) were recorded under 100 kg ha⁻¹ than the control. Maximum yield (260.83 q ha⁻¹) was recorded under nitrogen level 100 kg ha⁻¹ which was statistically at par with 75 kg ha⁻¹ (257.89 q ha⁻¹) as compared to control. Supply of nitrogen in the plant which was increases the mobilization and accumulation of photosynthesis.

Higher Crude fiber content (1.39 per cent) is significantly increases (Table 3) at higher dose of nitrogen

100 kg ha⁻¹ which was at par with 75 kg ha⁻¹ (1.37 per cent). Maximum chlorophyll content (50.45mg/100g) was observed in 100 kg ha⁻¹ than the control. Data presented in table-3 revealed that maximum nitrogen content (0.0440 per cent) in plant was recorded with 100 kg ha⁻¹ as compared to control. Maximum nitrogen and phosphorus uptake (11.55 and 11.75 kg) by plant were recorded under 100 kg ha⁻¹ than the control. Available N content in soil after harvesting (94.66 kg ha⁻¹) was observed in 100 kg ha⁻¹ than the control. Nitrogen content of leaves and fruit appeared to be due to improved nutritional environment in the dense root zone of the plant. Higher nutrient contents in plant also seem to be attributes higher functional activity of roots for longer duration under this treatment. Similar observations were also reported by Oloyede *et al.*, (2012).

Interactive effect

The interaction effect of vermicompost and nitrogen (Table-2 & 3) were found significant increase for number of primary branches per vine(11.32), length of leaf (31.30cm) at 60 days after sowing, Fruit set (59.60%), number of fruit per vine(10.40), Length of fruit (43.10cm), Weight of fruit(1071.50g), Total yield per vine(10.90 kg) and total yield (306.0 q ha⁻¹) were recorded under the treatment combination with 9 t ha⁻¹vermicompost level with 100 kg ha⁻¹ nitrogen than the control. The significant higher nitrogen content in plant (0.0458 per cent), nitrogen and phosphorus uptake by plant (13.9 & 14.2 kg ha⁻¹) were recorded with treatment combination at 9 t ha⁻¹ vermicompost level with 100 kg ha⁻¹ nitrogen than other combination. This is because of more photosynthetic formation and their translocation to sink. Secondly, it may be due to efficient use of both nutrients in physiological processes of plant. The uptake of these nutrients also increased due to development of dense rooting system of crop. Similar results have also been reported by Kumar *et al.*, (2012).

Data showed in table 3 that maximum net return (Rs. 151438.5) and B: C ratio (1.70) were recorded with treatment of combination at 6 t ha⁻¹vermicompost level with 100 kg ha⁻¹ nitrogen, which statistically at par with treatment of combination at vermicompost level 6 t ha⁻¹ and 75 kg ha⁻¹ nitrogen, than the other treatment combination.

Table 1. Response of vermicompost and nitrogen levels on growth, yield and quality of bottle gourd.

Treatments	Days to appearance of first female flower	Node No. at which first female flower appeared	Length of main vine (m) at harvest	Width of leaf (cm) at 60 DAS	Girth of fruit (cm)	Crude fiber content in fruit (%)	Chlorophyll content in plant (mg/ 100g)	K uptake (kg ha ⁻¹)	Available N in soil after harvest (kg ha ⁻¹)	Available P in soil after harvest (kg ha ⁻¹)	Available K in soil after harvest (kg ha ⁻¹)
Vermicompost level											
V ₀ (Control)	60.65	12.40	2.84	18.64	16.24	1.32	43.12	23.63	78.36	28.59	281.40
V ₁ (3 t ha ⁻¹)	59.83	12.30	3.63	23.81	20.75	1.33	45.36	33.41	85.84	31.39	309.42
V ₂ (6 t ha ⁻¹)	58.91	11.72	3.94	25.87	22.54	1.35	49.12	46.51	94.42	34.58	340.81
V ₃ (9 t ha ⁻¹)	59.41	11.52	3.99	26.19	22.83	1.39	49.54	47.23	99.28	36.35	357.34

SEm±	0.18	0.14	0.15	0.39	0.06	0.02	0.14	1.97	0.27	0.26	1.63
CD (P=0.05)	0.51	0.42	0.43	1.12	0.18	NS	0.40	5.70	0.77	0.75	4.70
Nitrogen levels											
N ₀ (control)	58.00	12.71	2.65	17.37	15.14	1.30	41.95	23.06	84.44	32.54	320.90
N ₁ (50 kg ha ⁻¹)	58.40	12.17	3.58	23.48	20.46	1.33	44.95	35.32	86.30	32.59	321.28
N ₂ (75 kg ha ⁻¹)	61.00	11.57	4.06	26.68	23.25	1.37	49.80	45.51	92.51	32.63	321.67
N ₃ (100 kg ha ⁻¹)	61.40	11.49	4.11	26.98	26.98	1.39	50.45	46.54	94.66	33.13	325.57
SEm±	0.18	0.14	0.15	0.39	0.06	0.02	0.14	1.97	0.27	0.26	1.63
CD (P=0.05)	0.51	0.42	0.43	1.12	0.18	0.07	0.40	5.70	0.77	NS	NS

Table 2. Effect of vermicompost and nitrogen levels on growth and yield of bottle gourd.

Treatment	No. of primary branches/vine at harvest	Length of leaf (cm) at 60 DAS	Percent fruit set	Number of fruit per vine	Length of fruit (cm)	Weight of fruit (g)	Total yield/vine (kg)	Yield (q ha ⁻¹)
Vermicompost levels								
V ₀ (Control)	7.82	19.52	37.12	7.34	26.86	537.38	5.48	153.48
V ₁ (3 t ha ⁻¹)	10.00	24.94	47.42	8.60	34.31	709.34	7.23	202.60
V ₂ (6 t ha ⁻¹)	10.86	27.09	51.52	9.38	37.28	859.81	8.76	245.57
V ₃ (9 t ha ⁻¹)	10.99	27.43	52.16	9.46	37.74	874.43	8.91	249.75
S.E.m±	0.03	0.07	0.03	0.03	0.02	2.27	0.02	2.23
C.D. (P=0.05)	0.09	0.21	0.08	0.08	0.06	6.55	0.07	7.78
Nitrogen levels								
N ₀ (Control)	7.29	18.19	34.59	7.10	25.03	460.50	4.70	131.53
N ₁ (50 kg ha ⁻¹)	9.86	24.59	46.76	8.33	33.84	704.30	7.18	201.16
N ₂ (75 kg ha ⁻¹)	11.20	27.94	53.13	9.46	38.44	902.94	9.20	257.89
N ₃ (100 kg ha ⁻¹)	11.32	28.25	53.73	9.71	38.88	913.23	9.30	260.83
SEm±	0.03	0.07	0.03	0.03	0.02	2.27	0.02	2.23
CD (P=0.05)	0.09	0.21	0.08	0.08	0.06	6.55	0.07	7.87
Interaction								
V ₀ + N ₀	5.80	14.40	27.30	5.10	19.70	332.10	3.40	94.80
V ₀ + N ₁	7.80	19.40	36.90	7.0	26.70	507.90	5.20	145.10
V ₀ + N ₂	8.80	22.0	41.90	8.60	30.30	651.10	6.60	186.0
V ₀ + N ₃	8.90	22.30	42.40	8.60	30.70	658.50	6.70	188.10
V ₁ + N ₀	7.40	18.30	34.90	7.30	25.20	438.30	4.50	125.20
V ₁ + N ₁	9.90	24.80	47.10	8.10	34.10	670.40	6.80	191.50
V ₁ + N ₂	11.30	28.20	53.50	9.50	38.70	859.40	8.80	245.50
V ₁ + N ₃	11.40	28.50	54.20	9.60	39.20	869.20	8.90	248.30
V ₂ + N ₀	8.00	19.90	37.90	8.0	27.40	531.20	5.40	151.70
V ₂ + N ₁	10.80	26.90	51.20	9.10	37.0	812.60	8.30	232.10
V ₂ + N ₂	12.30	30.60	58.20	10.20	42.10	1041.80	10.60	297.50
V ₂ + N ₃	12.20	30.90	58.80	10.30	42.60	1053.60	10.70	300.90
V ₃ + N ₀	8.10	20.20	38.30	8.0	27.70	540.30	5.50	154.30
V ₃ + N ₁	10.90	27.30	51.80	9.20	37.50	826.40	8.40	236.0
V ₃ + N ₂	12.40	31.0	58.90	10.30	42.60	1059.50	10.80	302.60
V ₃ + N ₃	12.50	31.30	59.60	10.40	43.10	1071.50	10.90	306.0
SEm±	0.05	0.14	0.05	0.05	0.04	4.53	0.04	5.45
CD (P=0.05)	0.17	0.42	0.15	0.16	0.11	13.09	0.13	15.74

Table 3. Effect of vermicompost and nitrogen levels on quality and economics of bottle gourd.

Treatment	N content in plant (%)	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	Net return (Rs./ ha)	B : C ratio
Vermicompost levels					
V ₀ (Control)	0.0400	6.20	6.49	64905.0	1.12
V ₁ (3 t ha ⁻¹)	0.0410	8.39	8.79	88397.0	1.20
V ₂ (6 t ha ⁻¹)	0.0432	10.75	11.18	107777.50	1.21
V ₃ (9 t ha ⁻¹)	0.0432	10.90	11.45	96117.30	0.92
SEm±	0.0001	0.13	0.10	-	-
CD (P=0.05)	0.0003	0.37	0.28	-	-
Nitrogen levels					
N ₀ (Control)	0.0393	5.19	5.82	25123.30	0.32
N ₁ (50 kg ha ⁻¹)	0.0411	8.30	8.91	79976.80	1.00
N ₂ (75 kg ha ⁻¹)	0.0431	11.19	11.44	125036.80	1.55
N ₃ (100 kg ha ⁻¹)	0.0440	11.55	11.75	127059.80	1.57
SEm±	0.0001	0.13	0.10	-	-
CD (P=0.05)	0.0003	0.37	0.28	-	-
Interaction					
V ₀ + N ₀	0.0377	3.60	4.0	18874.90	0.33
V ₀ + N ₁	0.0395	5.70	6.10	58191.60	1.01
V ₀ + N ₂	0.0411	7.60	7.80	90592.80	1.56
V ₀ + N ₃	0.0418	7.90	8.00	91960.80	1.57
V ₁ + N ₀	0.0385	4.80	5.40	27351.80	0.38
V ₁ + N ₁	0.0404	7.70	8.30	79525.20	1.08
V ₁ + N ₂	0.0421	10.30	10.60	122399.0	1.65
V ₁ + N ₃	0.0429	10.70	10.90	1245308.90	1.67
V ₂ + N ₀	0.0402	6.10	6.90	33599.80	0.38
V ₂ + N ₁	0.0423	9.80	10.50	97017.10	1.09
V ₂ + N ₂	0.0445	13.30	13.50	149054.40	1.68
V ₂ + N ₃	0.0458	13.80	13.90	151438.50	1.70
V ₃ + N ₀	0.0407	6.30	7.0	20663.60	0.20
V ₃ + N ₁	0.0421	9.90	10.80	85173.50	0.82
V ₃ + N ₂	0.0446	213.50	13.80	138101.0	1.33
V ₃ + N ₃	0.0454	13.90	14.20	140531.10	1.35
SEm±	0.00019	0.25	0.19	-	-
CD (P=0.05)	0.00055	0.73	0.55	-	-

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Influence of plant growth regulators on yield and quality of Karonda (*Carissa carandas* L.)

Abhiskta Khan and S.N. Ghosh*

Department of Fruits and Orchard Management, Faculty of Horticulture,
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur – 741252, West Bengal.

*Corresponding author's email: profsnghosh@yahoo.co.in

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Abstract

An experiment was conducted on 6 year-old- plants of karonda at the Horticultural Research Station of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal to know the effect of different growth regulators on fruit yield and physico-chemical composition of fruits. There were five treatments viz., NAA at 20, 40 ppm; GA at 20 and 40 ppm and control (water spray) which were sprayed two times i.e., at 50% flowering stage and 21 days after 1st spray. The experiment was conducted following the randomized block design having four replications. The study clearly indicated that plant growth regulators were effective at different concentration in increasing fruit yield and physico-chemical characteristics of fruits. Application of NAA at 20 ppm resulted in maximum fruit set (93.62%), fruit retention (83.0%) and fruit yield (4.07 kg/plant). The treatment also increased fruit weight and pulp content while GA at 20 ppm was found to be the best for increasing TSS (8.87⁰B), total sugars (6.05%), ascorbic acid (34.00 mg/100 g) and anthocyanin (3.87 mg/100 g pulp) contents followed by NAA 20 ppm. Considering the over all performance and lower market price, the NAA at 20 ppm is recommended for higher production of quality karonda fruits in new alluvial zone of West Bengal.

Key words : Fruit quality, fruit yield, karonda, plant growth regulators.

Introduction

Karonda (*Carissa carandas* L.), also known as karancha (Bengali), belongs to family Apocynaceae, originated in India, occurs mostly on sandy or rocky soil in a wild state. It is an evergreen diffuse, spiny shrub, occurs throughout arid tropic and sub-tropics and is grown for its attractive colour edible fruits. It thrives well as a rainfed crop in marginal and wastelands, and the plant hardly needs any care and gives yield with the minimum management. The fruits are eaten as a dessert when ripe. Mature fruits contain a high amount of pectin, which is used for preparation of different products such as jelly, jam, squash, sauce, syrup, etc. which are of great demand in the international market. The fruits are rich in protein, vitamin C and minerals, especially, iron (39.1 mg/100 g), calcium and phosphorus. In spite of high nutritive values and multipurpose uses of karonda, little attention has been paid on production aspect of the crop.

Karonda is usually grown in such land situation, lie waste or marginal land where fruit dropping seems to happen due to lack of nutrients and other factors. Beneficial effect of various plant growth regulators on fruit set and controlling fruit drop has been reported in many underutilized fruit crops like rose apple (Das *et al.*, 2006), aonla (Ghosh *et al.*, 2009), ber (Ghosh *et al.*, 2009),

pomegranate (Ghosh *et al.*, 2009) etc. but no report is available regarding beneficial role of plant growth regulators on karonda. Therefore, an investigation was made to determine the effect of plant growth regulators on fruit production and fruit quality of Karonda grown in alluvial soil.

Materials and Methods

The experiment was conducted at the Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal during 2014-2015 on 6 year old budded karonda plants of local elite type, planted at 2.5 m x 2.5 m spacing. The soil of the experimental orchard was sandy loam having soil pH 6.8, available N, P and K were 230.0, 35.20 and 86.0 kg/ha, respectively. The experimental site belongs to sub-tropical humid climate, where summer and winter are short and mild. The plants were fertilized with cow dung manure at 4 kg and N₁₀₀-P₅₀K₅₀ g/plant/year in two splits i.e. in June and September. The plants were maintained under rain fed condition. The experiment was laid out in Randomized Block Design with four replications having four plants per replication. There were five treatments with two growth regulators viz., NAA at 20, 40 ppm; GA at 20, 40 ppm and control (water spray). These chemicals were thoroughly sprayed early in the

morning, two times along with the control using teepol as surfactant. The first spray was given at 50% flowering stage and 2nd spray was 21 days later.

Fruit set was calculated from the tagged 100 flowers per plant. For observing fruit retention 50 fruits were tagged just after fruit set at pea stage and fruit retention was noted two months after tagging. Fruit yield was calculated by total number of fruits per plant at maturity multiplied with the average fruit weight. Fruit weight was measured at maturity on the basis of 20- fruits taken from each plant randomly with the help of a weighing balance. Pulp was extracted from the known weighted 20 fruits and thus calculated and expressed in percentage. The TSS was measured by hand refracto-meter while acidity, total, sugar and ascorbic acid content of fruit were determined following standard method (A.O.A.C., 1990). Anthocyanin content of fruit was measured by adding a mixture of ethanol and HCl to the sample and then filtering the extract by filter paper, the reading was taken in spectrophotometer at wave length of 535 nm.

Results and Discussion

The results from the investigation (Table 1) revealed that application of plant growth regulators resulted in increasing fruit set, fruit retention and consequently improved the yield. The fruit set (93.6%) and fruit retention (83.0%) was significantly highest in the plants sprayed with NAA at 20 ppm followed by GA at 20 ppm (91.50% and 80.8% respectively). In control, the fruit set and fruit retention were lowest (76.5% and 68.3% respectively). Beneficial role of NAA application in increasing fruit, set and fruit retention may be explained from the fact that exogenous application of auxin may help to increase its endogenous level which resulted in more fruit set in one hand and prevent the formation of abscission zone in other hand (Tomaszewska and Tomaszewska, 1970) resulting more fruit retention.

A significant and positive role on fruit yield was observed with the application of plant growth regulators (Table 1). All the treatments were better as compared to the control. Highest fruit yield (4.07 kg/plant) was recorded with foliar application of 20 ppm NAA and was more than double compared to control plants (1.55 kg/plant). Highest fruit yield with NAA 20 ppm was due to maximum fruit set and its retention. Beneficial effect of NAA at lower dose in yield increment was also noted by several workers in ber (Ghosh *et al.*, 2009), pomegranate (Ghosh *et al.*, 2009), aonla (Ghosh *et al.*, 2009), bael (Uniyal and Misra, 2015), etc. It was observed that effectiveness of NAA or GA concentration in yield increment was drastically reduced at their respective higher dose.

Fruit weight was significantly improved with the application of growth regulators and NAA at 20 ppm resulted in highest fruit weight 9.04 g as against 7.03 g in control (Table 2). Increase in fruit weight due to NAA application may be due to cell elongation and division with increased enzymatic activity (Leopld, 1958; Weaver, 1972). Pulp content, another important physical parameter in karonda from the point preservation of significantly varied in different treatments. The maximum pulp percentage 79.49% was found with treatment of NAA 20 ppm followed by 76.85% with GA 20 ppm and the lowest pulp content was noted from the control fruits (68.60%).

The total soluble solids content in the fruits was significantly increased with the growth regulators application and both NAA and GA were effective in this regard. Highest TSS content was measured from the fruits of the plants sprayed with GA 20 ppm (8.87^o Brix) followed by NAA 20 ppm (8.25^o Brix). In control plants, the TSS was measured lowest (6.25^o Brix). Beneficial effect of NAA and GA in improving TSS content was also noted in ber and pomegranate (Ghosh *et al.*, 2009). Fruit acidity did not vary significantly in different treatments. Total sugar, ascorbic acid and anthocyanin contents in the fruits were also increased with the application of growth regulators. Highest total sugars (6.05%), ascorbic acid (34.00 mg/100 g pulp) and anthocyanin (4.00 mg/100 g pulp) contents were recorded from the fruits of the plant sprayed with GA 20 ppm followed by NAA 20 ppm (5.95%, 32.50 mg and 3.87 mg/100 g pulp, respectively). The fruits from the control plants showed the lowest values in all the chemical parameters. Similar observation was recorded by Dutta *et al.*, (2006), who reported that NAA 20 ppm was effective in improving physical characters of the fruits of rose apple and water apple while GA 20 ppm was effective in improving the chemical constituents of above mentioned fruits. The results reported by Yadav and Chaturvedi (2005) are more or less in agreement with the present findings, who reported increment of TSS and total sugar contents in ber with the application of GA₃ at 30 ppm. Improvement in TSS and total sugar contents in the fruits due to GA and NAA application may be explained from the fact that application of these growth regulators after fruit set probably improved the internal physiology of leaves thereby causing better translocation of vital components in the fruit and assimilation as well as utilization of photosynthates in developing fruits leading to improvement in sugar contents (Ghosh *et al.*, 2009). Increase in ascorbic acid content in the fruit might be due to catalytic activity of plant bio-regulators on its biosynthesis from its precursor glucose-6-phosphate or inhibition of its conversion into dehydro ascorbic acid by enzyme ascorbic acid oxidase or both (Brahmachari and Rani, 2001).

Table 1. Effect of plant growth regulators on fruit set, fruit retention, fruit yield and physical characteristics of fruits of karonda

Treatment	Fruit set (%)	Fruit retention (%)	Yield /plant (kg)	Fruit weight (g)	Pulp content (%)
NAA 20 ppm	93.6 (75.35)	83.0 (65.65)	4.07	9.04	79.49
NAA 40 ppm	84.8 (67.05)	76.4 (60.94)	2.90	8.13	74.42
GA 20 ppm	91.5 (73.05)	80.8 (64.01)	3.59	8.56	76.85
GA 40 ppm	81.7 (64.67)	72.6 (58.44)	2.49	8.00	70.64
Control	76.5 (61.00)	68.3 (55.73)	1.55	7.03	68.60
SEm (±)	0.41	0.64	0.08	0.16	0.49
CD 5%	1.29	2.01	0.26	0.49	1.53

Figures in the parenthesis are angular transformed values

Table 2. Effect of plant growth regulators on chemical composition of karonda fruits

Treatment	TSS (⁰ Brix)	Acidity (%)	Total sugars (%)	Ascorbic acid (mg/100g)	Anthocyanin content (mg/100g)
NAA 20 ppm	8.25	2.12	5.95	32.50	3.87
NAA 40 ppm	7.25	2.32	5.85	30.25	3.15
GA 20 ppm	8.87	2.07	6.05	34.00	4.00
GA 40 ppm	8.21	2.34	5.90	31.25	3.67
Control	6.25	2.48	4.20	28.50	2.95
SEm (±)	0.18	0.01	0.01	0.03	0.06
CD 5%	0.57	NS	0.03	0.99	0.20

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Assessment of morphological and biochemical characters of date palm cultivars

Ganga Datt Awasthi^{1*}, R.S. Singh² and R. Bhargava²

¹ Department of Horticulture, S. K. Rajasthan Agricultural University, Bikaner - 334 006, INDIA

² ICAR-Central Institute for Arid Horticulture, Bikaner - 334 006, INDIA

*Corresponding author email: gangadatt123@gmail.com

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Abstract

Eight date palm cultivars i.e. Khadrawy, Shamran, Zahidi, Braim, Chipchap, Sabiah, Seddami and Medjool commonly grown in Bikaner were studied for their morphological and physiochemical characters at ICAR-CIAH, Bikaner, Rajasthan, India during the year 2015-16. The results revealed that differences in vegetative characters were statistically significant except in the length of leaves. The fruit colour, size, weight, stone size and grooves in stone are useful characters for identification of date palm cultivars and the maximum plant height (5.34 m) and length of pinnae (44.79 cm) was recorded in cv. Seddami whereas, minimum height (2.16 m) and length of pinnae (33.64 cm) in cv. Khadrawy. Breadth of pinnae range from 1.96 cm in cv. Shamran to 2.85 cm in Medjool. Maximum leaf length (3.25 m) was recorded in cv. Braim whereas, minimum in cv. Medjool (2.40 m). Among the varieties maximum fruit size i.e. length (4.41 cm), dia (2.92 cm), fruit weight (21.49 g), stone weight (1.97 g) and pulp: stone ratio (12.93) was produced by cv. Medjool and minimum fruit size i.e. fruit length (2.91 cm), diameter (1.93 cm), fruit weight (7.62 g) and stone weight (1.09 g) in cv. Sabiah. The total soluble solid (36.55 %), total sugars (36.35%), reducing sugar (31.54%) was recorded maximum in Braim whereas, minimum total soluble solid (32.83 %) and reducing sugar (27.72%) in a Sabiah, total sugars (31.39%) in cv Shamran. Non reducing sugars were maximum (5.50%) in a Seddami and minimum in cv. Shamran (2.70%). Maximum acidity content was recorded (0.31%) in Sabiah and minimum (0.21%) in Braim, maximum ascorbic acid was recorded in Medjool (7.83 mg/100g pulp) and minimum in Shamran (4.65 mg/100 g).

Keywords: date palm, morphological and biochemical characters

Introduction

Date palm (*Phoenix dactylifera* L.) is one of oldest cultivated plant by human kind and used as food for 6000 years. It is a dioecious plant, which belongs to the family Palmaceae and has diploid chromosome number $2n=2x=36$. Date palm, also known as *khajoor* or *kharek* is an ancient indigenous fruit of countries around the Persian Gulf (Al Ugaydy, 2000). The cultivation of date palm is increasing day by day because of its vast potential in arid and semi-arid parts of India. The cultivation of date palm on commercial basis in the Thar Desert will be helpful in saving of foreign exchange which is incurred on import of date fruits and products. In addition to this, it will provide best utilization of command irrigated area under Thar Desert, prosperity to the farmers of the area and employment generation opportunities in the region, as well

as nutritious food to rural inhabitants of arid region. Different products like sugar, starch, vinegar, juice, toffees, wine, chutney, jam, pickles are prepared from date palm fruits. The date palm fruit have been recognized for their highly nutritive and caloric values. Date fruit provides abundant quantity of iron, potassium, calcium, nicotinic acid and small amount of protein, copper, magnesium, sulphur and vitamin A, B & B2. Date pulp contains moisture (20%), sugar (60-65%), fiber (2.5%), protein (2%) and less than 2 % fat and pectic substances (Gopalan *et al.*, 1985). Caramel colour, produced from dates, can be used in food and pharmaceuticals industries (Zaid *et al.*, 2007). The date palm leaves are also used for making temporary huts and preparation of baskets, broom, ropes and handicraft items. The seed kernel is used in making cattle feed (Srivastav *et al.*, 2013). The varieties like Halawy, Zahidi, Khalas,

Barhee, Medjool and Khadrawy have been found suitable for production of higher yield in Western Rajasthan (Chandra *et al.*, 1992; Singh *et al.*, 2003). Morphological and biochemical assessment is very important to identify the elite cultivars having economics importance. This is of great importance to further study for crop improvement, selection, multiplication and preserving the crop product. Morphology is the bird eye view for further research work, which creates bench mark for correlating with its molecular aspects. Morphological and biochemical analysis was done at Bikaner region for making the general view on the evaluation and identification of eight date palm cultivars.

Materials and Methods

The experiment was conducted at the Research Farm and the Plant Physiology Laboratory of Central Institute for Arid Horticulture (CIAH) during the year of 2015 with an altitude of 234.7 m above sea level at latitude 28° 01' N and longitude 73° 22' E. According to Agro Ecological region map brought out by National Bureau of Soil Survey and Land Use Planning, Bikaner falls under Agro ecological region No.2 (M 9 E 1) under arid ecosystem (Hot Arid Eco-region with desert and saline soils), which is characterized by deep, sandy and coarse loamy, desert soils with low water holding capacity, hot and arid climate. PET (Potential Evapo-transpiration) in this region ranges between 1500-2000 mm and annual average rainfall between 200-260 mm. The temperature may go as high as 48°C while in the winters it may dip down to 0°C. The palm uniform in size, vigour and bearing stage were selected from CIAH date palm research farm. Eight palm each of the cultivars Khadrawy, Shamran, Zahidi, Braim, Chipchap, Sabiah, Seddami and Medjool were selected. There were eight varieties with three replications planted at 8 x 8 m distance in square system of planting. In growth parameters, height of plant, length of leaves and size of pinnae were recorded. For the fruiting parameters, length of bunch, number of strands/bunch, number of fruit per strand, fruit size, fruit weight, pulp:stone ratio etc. were observed during the study. The ripe fruit (turning stage green to yellow i.e. doka stage) were harvested for taking the observations and biochemical analyses.

Vegetative characters

Height of the plant (m) - The height of individual tree (m) was measured with the help of long straight bamboo stick and measuring tape. **Length of leaves:** Randomly selected three leaves from each tree were selected for recording leaf length and mean value of each tree was taken. **Size of pinnae (cm)** - Randomly selected five pinnae was taken and length as well as breadth of the pinnae was measured with the help of measuring scale.

Fruit characters

Length of bunch was recorded by using measuring tape, number of strand/bunch and number of fruit per strand were counted. For lengths of strand (cm) three strands were selected and the length of strands was measured and average length of strand was calculated. For numbers of berries per strand- three strands were randomly selected from a bunch and number of berries of each strand were counted at the time of harvesting and then average number of fruits per strand was worked out. For weight of berry (g) - five matured fruits were selected to quantify the weight of berry (g) at doka stage. The fruits were weighed with the help of balance and average weight of single berry was calculated. For stone weight (g) - Stones from the fruits selected for measuring size were separated out and weighed and average stone weight was calculated.

Pulp-stone ratio: The pulp-stone ratio was calculated using the following formula;

$$\text{Pulp:stone ratio} = \frac{\text{Pulp weight (g)}}{\text{Stone weight (g)}}$$

Biochemical parameters

Biochemical parameters were assessed viz. T.S.S. through hand refractometer (0-50° Brix) (AOAC, 1990), titrable acidity using Phenolphthalein as an indicator (AOAC, 1990), reducing sugar (Nelson's method), total sugar (Anthrone reagent) and ascorbic acid (Colorimetric micro method, Grick *et al.*, 1953).

Statistical Analysis

The experiment was laid out in Completely Randomized Design. Data obtained on various characters were analyzed statistically according to the analysis of variance techniques as suggested by Panse and Sukhatme, (1985); Chandel, (1999). The critical difference (CD) was calculated to access the significance or non-significance of difference between treatment means.

Result and discussion

Vegetative characters

Analysis of the morphological parameters revealed that the maximum plant height (5.34 m) was recorded in cv. Seddami whereas, minimum in cv. Khadrawy (2.17 m). There was statistically significant difference in height of palm. The maximum leaf length was recorded in cv. Braim (3.25 m) and lowest in cv. Medjool (2.40 m). Significantly maximum length of pinnae was recorded in cv. Seddami (44.79 cm) and minimum in cv. Khadrawy (33.64 cm). Similarly, breadth of pinnae was significantly higher in cv. Medjool (2.85 cm) and lowest in cv. Shamran (1.96 cm) as represented in table 1.

The variation in the size of leaflet/pinnae was statistically significant. The variation in size of pinnae among the

cultivars have been described by Gothwal *et. al.*, (2013).

Table 1. Vegetative characteristics of date palm cultivars

Cultivars	Height of plant(m) ±S.D.	Length of leaves(m) ±S.D.	Length of pinnae(cm) ±S.D.	Breadth of pinnae (cm) ±S.D.
Khadrawy	2.17±0.20	2.99 ±0.57	33.64 ±3.87	2.80±0.28
Shamran	3.18 ±0.25	3.21 ±0.12	40.44 ±3.48	1.96±0.08
Zahidi	3.10 ±0.52	2.71 ±0.32	34.36 ±3.43	2.64±0.15
Braim	3.32 ±0.54	3.25 ±0.75	41.47±2.79	2.08±0.03
Chipchap	3.03 ±0.25	3.15 ±0.42	41.89 ±3.47	2.36±0.30
Sabiah	3.27 ±0.90	2.91 ±0.28	36.53 ±2.11	2.63±0.28
Seddami	5.34 ±0.83	2.96 ±0.30	44.79 ±3.16	2.17±0.19
Medjool	3.38 ±0.63	2.40 ±0.18	38.92 ±6.97	2.85±0.37
SEm±	0.31	0.25	2.14	0.13
CD(P=0.05)	0.96	0.75	6.49	0.39

Bunch and Fruit characters

The maximum length of bunch was recorded in cv. Zahidi (82.70 cm), which was significantly higher and the minimum length of bunch was recorded in cv. Khadrawy (53.86 cm). The maximum number of strands/bunch was observed in cv. Sabiah (55.66), which was significantly higher over other cultivars and lowest was recorded in cv. Braim (34.66) as represented in table 2. Singh *et al.*, (2006) found significantly higher number of strand in Halaway followed by Sabiah, Seddami, Khadrawy, Shamran, Braim and Chipchap. Fruit characters were statistically significant given in table 2 and table 3. Significantly higher number of berries per strand recorded in cv. Zahidi (24.03) and lowest was in cv. Seddami (13.03). The maximum length of berry was observed in the cultivar Medjool (4.41cm) and minimum in cv. Sabiah (2.92 cm). Similarly, maximum breadth of berry was noted in cultivar Medjool (2.92 cm) and minimum in cv. Sabiah (1.93 cm). Fruit weight is an

important economic index for date palm fruits yield and it was recorded maximum in cv. Medjool (21.49 g), while minimum in cv. Sabiah (7.62g). Significantly higher pulp:stone ratio was observed in cv. Medjool (12.92) and lowest in Seddami (5.52). From the table 4 the maximum length of stone was observed in cultivar Chipchap (2.49 cm) and it was lowest in sabiah (1.99 cm). Similarly, maximum breadth of stone was recorded in Seddami (0.83cm) and lowest in cv. Braim (0.62cm). Weight of stone was recorded highest in cv. Seedami (1.67g) and lowest in cv. Sabiah (1.09 g). Among the eight cultivars studied, Zahidi, Braim, Chipchap, Seddami and Khadrawy were yellow in colour whereas, Shamran was Yellow-red-tinge. The berry of cv. Medjool was orange while cv. Sabiah was red in colour at doka stage of harvest. Stone groove of date palm cultivars were recorded and classified as broad, deep, medium and narrow.

Table 2. Bunch parameters and pulp: stone ratio of date palm cultivars

Cultivars	Length of bunch(m) ±S.D.	No. of strand bunch ⁻¹ ±S.D.	No. of berries strand ⁻¹ ±S.D.	Pulp :Stone ratio ±S.D.
Khadrawy	53.86±3.25	40.33±4.93	19.00±1.40	6.47±0.61
Shamran	59.13±7.86	40.00±4.35	19.26±1.80	7.24±0.52
Zahidi	82.70 ±6.57	36.33±3.21	24.03±0.55	7.07±0.30
Braim	58.00 ±4.00	34.66±3.05	16.05±2.20	6.69±0.52
Chipchap	74.83±14.21	39.66±5.68	15.73±1.79	8.21±1.03
Sabiah	65.66±7.76	55.66±3.05	16.05±2.31	6.03±1.29
Seddami	55.20±3.36	40.16±2.02	13.03±1.15	5.52±0.63
Medjool	67.66±6.52	42.00±4.00	13.38±2.93	12.92±1.14
SEm±	4.26	2.38	1.07	0.49
CD(P=0.05)	12.93	7.24	3.25	1.50

Table 3. Fruit characteristics of date palm cultivars

Cultivars	Fruit wt. (g) $\pm$ S.D.	length of berry (cm) $\pm$ S.D.	Breadth of berry(cm) $\pm$ S.D.
Khadrawy	8.93 $\pm$ 0.12	3.25 $\pm$ 0.02	2.13 $\pm$ 0.02
Shamran	10.31 $\pm$ 0.31	3.62 $\pm$ 0.20	2.24 $\pm$ 0.18
Zahidi	9.19 $\pm$ 1.08	3.32 $\pm$ 0.24	2.49 $\pm$ 0.62
Braim	9.14 $\pm$ 0.23	3.59 $\pm$ 0.08	2.07 $\pm$ 0.03
Chipchap	11.98 $\pm$ 0.96	3.90 $\pm$ 0.14	2.25 $\pm$ 0.08
Sabiah	7.62 $\pm$ 1.003	2.92 $\pm$ 0.18	1.93 $\pm$ 0.12
Seddami	10.84 $\pm$ 0.09	3.61 $\pm$ 0.01	2.30 $\pm$ 0.08
Medjool	21.49 $\pm$ 1.75	4.41 $\pm$ 0.13	2.92 $\pm$ 0.12
SEm $\pm$	0.54	0.08	0.14
CD(P=0.05)	1.66	0.24	0.44

Table 4. Stone characters of date palm cultivars

Cultivars	Stone wt. (g) $\pm$ S.D.	Length of stone (cm) $\pm$ S.D.	Breadth of Stone (cm) $\pm$ S.D.
Khadrawy	1.2 $\pm$ 0.08	2.10 $\pm$ 0.01	0.69 $\pm$ 0.047
Shamran	1.25 $\pm$ 0.05	2.24 $\pm$ 0.04	0.69 $\pm$ 0.011
Zahidi	1.13 $\pm$ 0.09	2.17 $\pm$ 0.13	0.69 $\pm$ 0.005
Braim	1.19 $\pm$ 0.10	2.35 $\pm$ 0.05	0.62 $\pm$ 0.032
Chipchap	1.30 $\pm$ 0.06	2.49 $\pm$ 0.12	0.63 $\pm$ 0.023
Sabiah	1.09 $\pm$ 0.06	1.99 $\pm$ 0.13	0.63 $\pm$ 0.011
Seddami	1.67 $\pm$ 0.16	2.40 $\pm$ 0.03	0.83 $\pm$ 0.043
Medjool	1.54 $\pm$ 0.015	2.47 $\pm$ 0.02	0.78 $\pm$ 0.005
SEm $\pm$	0.05	0.048	0.016
CD(P=0.05)	0.15	0.14	0.049

Biochemical characters

The highest total soluble solids (TSS) were recorded in cultivar Braim (36.65%) and lowest in cv. Sabiah (32.83%). Gothwal et al. (2013) reported that total soluble solid in date palm range from 32.0 brix-39.0 brix. The maximum titratable acidity (%) was recorded in cv. Sabiah (0.31%) and the lowest acidity was observed in cv. Braim (0.21%). The highest ascorbic acid content was recorded in cv. Medjool (7.83 mg/100g pulp) and lowest in cv. Shamran (4.65 mg/100g). Meena et al. (2013) reported that the maximum ascorbic acid content was found in Halawy (3.59 mg/100g) and minimum in Zahidi (2.37 mg/100 g) fruit pulp. Similar finding had been reported by Alizai et al.

(2005). Total sugars in fruits of eight date palm cultivars were observed at doka stage and the highest total sugars content was found in cv. Braim (36.35%) and it was lowest in cv. Shamran (31.39%). The highest reducing sugar content was recorded in the cultivar Braim (31.54%) and the lowest reducing sugar in Sabiah (27.72%). The highest non reducing sugar content was recorded in the cultivar Seddami (5.50%) and lowest in cultivar Shamran (2.70%). Gothwal et al. (2013) reported that total sugars content of fruit ranged between 31.09 % (Dayari) to 36.05% (Halawy). Nehra et al. (1988) reported the non reducing sugar content in different cultivars such as Khadrawy (3.67%), Hillawi (2.1%), Medjool (10.10%), and Zaglou (7.17 %).

Table 5. Total soluble Solid (0Brix), Acidity (%) and Ascorbic Acid (mg/100 g pulp) in date palm fruits

Cultivars	Total Soluble Solid (TSS) ⁰ Brix $\pm$ SD	Acidity (%) $\pm$ SD	Ascorbic Acid (mg/100g) $\pm$ SD
Khadrawy	34.03 $\pm$ 1.58	0.28 $\pm$ 0.06	4.72 $\pm$ 0.91
Shamran	34.08 $\pm$ 0.45	0.30 $\pm$ 0.02	4.65 $\pm$ 0.23
Zahidi	33.05 $\pm$ 1.05	0.29 $\pm$ 0.03	5.94 $\pm$ 0.83
Braim	36.65 $\pm$ 1.43	0.21 $\pm$ 0.02	7.01 $\pm$ 0.93
Chipchap	36.43 $\pm$ 2.22	0.23 $\pm$ 0.02	7.46 $\pm$ 1.33
Sabiah	32.83 $\pm$ 1.47	0.31 $\pm$ 0.01	6.18 $\pm$ 0.45
Seddami	33.56 $\pm$ 0.61	0.30 $\pm$ 0.02	4.74 $\pm$ 0.27
Medjool	33.38 $\pm$ 0.86	0.30 $\pm$ 0.04	7.83 $\pm$ 1.22
SEm $\pm$	0.76	0.019	0.5
CD(P=0.05)	2.30	0.058	1.50

Table 6. Total sugars (%), Reducing sugars (%) and Non Reducing sugars (%)

Cultivars	Total Sugar (%) $\pm$ SD	Reducing Sugar (%) $\pm$ SD	Non Reducing Sugar (%) $\pm$ SD
Khadrawy	33.60 $\pm$ 1.42	30.93 $\pm$ 1.15	2.72 $\pm$ 0.38
Shamran	31.39 $\pm$ 0.98	28.69 $\pm$ 0.94	2.70 $\pm$ 0.42
Zahidi	32.50 $\pm$ 0.93	28.43 $\pm$ 0.48	4.07 $\pm$ 1.37
Braim	36.35 $\pm$ 1.68	31.54 $\pm$ 0.95	4.81 $\pm$ 0.76
Chipchap	35.20 $\pm$ 1.14	30.19 $\pm$ 1.73	5.01 $\pm$ 1.47
Sabiah	31.71 $\pm$ 3.00	27.72 $\pm$ 2.15	3.98 $\pm$ 0.99
Seddami	33.42 $\pm$ 2.07	27.91 $\pm$ 1.03	5.50 $\pm$ 1.45
Medjool	33.20 $\pm$ 1.69	29.93 $\pm$ 1.05	4.65 $\pm$ 1.12
SEm $\pm$	1.004	0.74	0.62
CD(P=0.05)	3.01	2.22	1.87

Conclusion

Morphological characters such as height of plant, size of leaf, pinnae, bunch and fruit characters were assessed for identification of date palm cultivars. It was observed that differences in vegetative characters of different cultivars were statistically significant except in length of leaves. The fruit colour, size, weight, stone size etc are useful characters for identification of date palm cultivars.

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Efficacy of *Trichoderma harzianum* and *Pseudomonas fluorescens* against wilt of cumin (*Cuminum cyminum* L.)

S.L. Godara, Suresh Kumar* and N.K. Pareek

Agricultural Research Station, SK Rajasthan Agricultural University, Bikaner-334006

*Corresponding author email: lorask77@gmail.com

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Abstract

Efficacy of bioagents like *T. harzianum* and *P. fluorescens* alone or with combined inoculation as seed treatment and soil application along with or without vermicompost were evaluated against wilt of cumin caused by *Fusarium oxysporum* f. sp. *cumini* under field conditions Rabi 2013-14 and 2014-15. Among all the treatments, combined inoculation of *T. harzianum* + *P. fluorescens* as seed treatment (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) along with vermicompost resulted minimum disease incidence (15.82%) and highest per cent disease control (64.42%) followed by *T. harzianum* + *P. fluorescens* combined application as seed treatment (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) without vermicompost. These treatments were also found effective on the dry weight of cumin plants. The shoot, root lengths and cumin seed yield were significantly increased in response to bioagent treatments. Highest shoot, root lengths and seed yield were also recorded in combined inoculation of bioagent treatments i.e. *T. harzianum* + *P. fluorescens* as seed treatment (4+4 gm/kg seed) and soil application along with vermicompost (2.5+2.5 kg/ha.) closely followed by *T. harzianum* + *P. fluorescens* seed treatment (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) without vermicompost. Whereas, rest of the treatments were found least effective on shoot, root lengths and seed yield of the cumin.

Keywords: Cumin, wilt, *Fusarium oxysporum* f. sp. *cumini*, *T. harzianum* and *P. fluorescens*.

Introduction

Cumin (*Cuminum cyminum* L.) locally known as Zeera, belonging to the family Apiaceae and believed to have originated from Egypt. It is grown extensively in South-Eastern Europe and North Africa bordering the Mediterranean sea and in India and China (Chattopadhyay and Maiti, 1990). In India, cumin is mainly grown in the states of Rajasthan, Gujarat, Uttar Pradesh and Tamil Nadu. Rajasthan and Gujarat states contribute 56% of total cumin production in the country (Sree Kumar, 1994). India is the largest producer and consumer of cumin crop. India contributes about 70% of world production followed by Syria 11%, Iran and Turkey 6% each respectively (Anon, 2008). The cumin seeds have an aromatic fragrance and used in food beverages, pharmaceuticals and perfumery. The cumin oil contains cuminaldehyde, hydrocarbons and oxygenated compounds (Chattopadhyay and Maiti, 1990). Wilt caused by *Fusarium oxysporum* (Schlecht) Snyder and Hans. f. sp. *cumini* (Prasad and Patel, 1963) is an endemic problem in most of cumin growing areas of the country. Vyas and Mathur (2002) recorded loss in seed yield to the extent of 35% due to this disease in Rajasthan. The pathogen is seed as well as soil-borne in nature. In absence of host crops, it survives in the soil mostly as chlamydospore (Mathur and Mathur, 1970).

With the increasing awareness of possible deleterious effects of ecosystem due to pesticide usage and growing interest in pesticide free agricultural products, the biological control of plant pathogens have received considerable attention. Biological control of plant pathogens by microorganisms has been considered as a natural and environmentally acceptable alternative to the existing chemical treatment methods (Baker and Paulitz, 1996). Hence, use of suitable bioagents alone and in combinations with organic substrates stands good alternatives for effective management of this pathogen (Mukhopadhyay, 1994; Chawla and Gangopadhyay, 2009; Gangopadhyay and Ram Gopal, 2010). Therefore, the present investigation was to evaluate combined effect of seed treatment and soil application of bioagents along with organic substrate against wilt of cumin. In the present experiment we carried out with alone and combined inoculation of *T. harzianum* with *P. fluorescens* to evaluate its efficacy against this pathogen.

Materials and Methods

Isolation and identification of the pathogen

Wilt infested cumin plants were collected from the field and gently washed in tap water to remove the soil and other extraneous materials adhering on root surface. The washed plant roots were cut into small pieces and surface

sterilized in 0.1 % HgCl₂ solution in Petri dishes for 1 to 2 minutes followed by washing in sterilized distilled water. The surface sterilized plant root pieces were transferred to potato dextrose agar (PDA) medium in Petri dishes. The Petri dishes were incubated in BOD incubator for seven days at 25 ± 1 °C for growth of the pathogen. The culture was observed under microscope and identified according to its spores, morphology and colony characteristics. The stock culture was kept in refrigerator at 4 °C for further studies.

Bioagents collection and preparation of formulations

Two bioagents viz., *Trichoderma harzianum* and *Pseudomonas fluorescens* obtained from the culture collection of the Department of Plant Pathology, College of Agriculture, SKRAU, Bikaner were used in the present study. These bioagents were isolated from the rhizosphere soils of this region. Antagonistic potentiality of these bioagents against *Fusarium oxysporum* f. sp. *cumini* was tested under laboratory conditions. Talc based formulations of these bioagents were prepared in the laboratory for testing their efficacy against cumin wilt under field conditions.

Trichoderma harzianum

T. harzianum was mass cultured on potato dextrose broth medium. For this purpose, mycelial discs (5 mm diameter) taken from periphery of actively growing colony of fungus raised on potato dextrose agar media in Petri dishes were transferred in 250 ml Erlenmeyer flasks containing 70 ml potato dextrose broth media and incubated at 26 ± 1 °C for 15 days. The biomass was homogenized and mixed with talc powder (1:2 ratio) and allowed to dry in shade. Carboxymethyl cellulose was added at 6 g kg⁻¹ talc preparation as a sticker and mixed thoroughly. The colony forming units (CFU) of the preparation was determined using *Trichoderma* selective medium (TSM). The CFU of the bioagents prepared was nearly 10⁹ g⁻¹ formulation.

Pseudomonas fluorescens

The culture of *P. fluorescens* was maintained on *Pseudomonas* agar *fluorescens* (PAF) medium in slants. A loop full of culture was transferred to Erlenmeyer flask containing 70 ml sterilized King's B broth (King, *et al.*, 1954) and incubated at 27 ± 1 °C for 72 hrs. The media containing the bacterial growth was mixed with the talc powder in 1:2 ratio and dried in shade. The mixture was sieved to obtain fine powder. Carboxymethyl cellulose was added at 6 g kg⁻¹ talc preparation and mixed thoroughly. The CFU of the preparation was determined in *Pseudomonas* agar *fluorescens* media which was approximately 10¹² g⁻¹ formulation.

Management of cumin wilt under field conditions

The field trials were conducted on management of wilt of cumin using bioagents alone or with combination during the cropping season Rabi-2013-14 and 2014-15 using cumin variety RZ-19. Talc based formulations of viz., *T. harzianum* and *P. fluorescens* were used for seed treatment and soil application along with vermicompost at 5 tonnes/ha. was applied in field soil. Nine treatments viz., *T. harzianum* seed treatment (8 gm/kg seed), *T. harzianum* seed treatment (8 gm/kg seed) and soil application (5 kg/ha.) along with vermicompost, *T. harzianum* + *P. fluorescens* combined application as a seed treatment (4+4 gm/kg seed), *T. harzianum* + *P. fluorescens* combined application as a seed treatment (4+4 gm/kg seed) and soil application (2.5 +2.5 kg/ha.) along with vermicompost, *P. fluorescens* alone seed treatment (8 gm/kg seed), *P. fluorescens* seed treatment (8 gm/kg seed) and soil application (5 kg/ha.) along with vermicompost, *T. harzianum* + *P. fluorescens* combined application as seed treatment (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) without vermicompost, *T. harzianum* alone seed treatment (8 gm/kg seed) and soil application (5 kg/ha.) without vermicompost and control (without any bioagents treatment) were tested randomized block design having plot size 4.5x3 m². Each treatment was replicated thrice. The trial was conducted under artificial soil inoculation conditions. For this purpose, the *F. oxysporum* f. sp. *cumini* isolate were multiplied on sand maize meal (2:1) medium in Erlenmeyer flasks. These flasks containing the sterilized media were inoculated with respective *F. oxysporum* f. sp. *cumini* cultures and incubated at 25 ± 1 °C for 15 days. Sand maize meal inocula of *F. oxysporum* f. sp. *cumini* was applied at 50 g per plot (4.5x3 m²) and mixed thoroughly on top surface of soil using a hand rack. Standard agronomic practices recommended for its cultivation in this region was followed. In case of control, the untreated seeds were sown. Observations on wilt incidence were recorded periodically. The shoot length, root length and dry weight of cumin plants were recorded at maturity and seed yield was recorded at harvest. The shoot length, root length and dry weight of five plants for each replication were recorded.

Calculation and statistical analysis

Disease incidence (%) and disease control (%) in field experiments were calculated as follows:

$$\text{Disease incidence (\%)} = \frac{\text{No. of diseased plants}}{\text{Total No. of plants germinated}} \times 100$$

$$\text{Disease control (\%)} = \frac{\text{Disease incidence in untreated control (\%)} - \text{Disease incidence in treated control (\%)}}{\text{Disease incidence in untreated control (\%)}} \times 100$$

The data of per cent disease incidence in the experiment was transformed to their Arcsin values (Fisher

and Yates, 1963). The statistical analyses of the data of all field experiments were analyzed following Randomized Block Design (Cochran and Cox, 1957).

Results and Discussion

The results revealed that all the treatments significantly suppress the wilt incidence of cumin with the application of respective bioagents as compare to control (Table 1). Treatment *T. harzianum* + *P. fluorescens* combined application as a seed treatment (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) along with vermicompost resulted minimum disease incidence (15.82%) and highest per cent disease control (64.42%) followed by seed treatment with *T. harzianum* + *P. fluorescens* (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) as a combined application without vermicompost. The seed treatment of *T. harzianum* + *P. fluorescens* (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) along with vermicompost was statistically at par with treatment *T. harzianum* + *P. fluorescens* combined application as seed treatment (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) without vermicompost. The disease control efficacy in this combined bioagent treatment i.e. seed treatment by *T. harzianum* + *P. fluorescens* (4+4 gm/kg seed) and soil application along with vermicompost (2.5+2.5 kg/ha.) was significantly higher than seed treatment (8 gm/kg seed) and soil application (5 kg/ha.) of *T. harzianum* along with vermicompost alone treatment. Further, the treatments *P. fluorescens* seed treatment (8 gm/kg seed) and soil application (5 kg/ha.) along with vermicompost, combined seed treatment with *T. harzianum* + *P. fluorescens* (4+4

gm/kg seed), *T. harzianum* seed treatment (8 gm/kg seed) and soil application (5 kg/ha.) without vermicompost and alone *T. harzianum* seed treatment (8 gm/kg seed) were also provide more than 40 per cent disease control. While, the seed treatments with *P. fluorescens* alone (8 gm/kg seed) were found least effective in controlling of the wilt incidence of cumin on the basis of pooled data.

Effect of bioagent treatments on the dry weight of cumin plants was also evaluated. The highest dry weight of cumin plants were recorded in the combined bioagent treatment with *T. harzianum* + *P. fluorescens* as a seed treatment (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) along with vermicompost. Maximum dry weight of cumin plants were recorded in this treatment was statistically significant as compare to the combined treatment of *T. harzianum* + *P. fluorescens* seed treatment (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) without vermicompost and rest of the treatments. The treatment *T. harzianum* seed treatment (8 gm/kg seed) and soil application (5 kg/ha.) along with vermicompost, seed treatment and soil application of *T. harzianum* along with vermicompost, *P. fluorescens* seed treatment (8 gm/kg seed) and soil application (5 kg/ha.) along with vermicompost, *T. harzianum* + *P. fluorescens* combined bioagent seed treatment (4+4 gm/kg seed) and *T. harzianum* seed treatment (8 gm/kg seed) and soil application (5 kg/ha.) without vermicompost were also found effective on dry weight of cumin plants. Whereas, rest of the treatments were recorded least effective on cumin plants dry weight (Table 1).

Table 1. Effect of bioagents against disease incidence and dry weight of cumin plants (Pooled 2013 and 14)

Treatments	Disease incidence (%)		Pooled	Disease Control (%)	Dry weight (gm/plant)		Pooled	Increase over control (%)
	2013	2014			2013	2014		
<i>T. harzianum</i> (ST @ 8 gm/kg seed)	25.42 (30.27)	27.33 (31.50)	26.38 (30.89)	40.67	1.31	1.26	1.28	33.12
<i>T. harzianum</i> (ST @ 8 gm/kg seed and SA- 5 kg/ha.) along with vermicompost	18.64 (25.42)	21.58 (27.67)	20.11 (26.54)	54.76	1.57	1.53	1.55	44.50
<i>T. harzianum</i> + <i>P. fluorescens</i> (ST @ 4+4 gm/kg seed)	23.28 (28.84)	24.75 (29.82)	24.01 (29.33)	45.99	1.38	1.33	1.36	36.65
<i>T. harzianum</i> + <i>P. fluorescens</i> (ST @ 4+4 gm/kg seed and SA- 2.5+2.5 kg/ha.) along with vermicompost	14.75 (22.58)	16.89 (24.27)	15.82 (23.42)	64.42	1.75	1.71	1.73	50.48
<i>P. fluorescens</i> (ST @ 8 gm/kg seed)	28.44 (32.22)	30.44 (33.48)	29.44 (32.85)	33.77	1.26	1.19	1.23	30.03
<i>P. fluorescens</i> (ST @ 8 gm/kg seed and SA- 5 kg/ha.) along with vermicompost	20.78 (27.09)	22.39 (28.22)	21.58 (27.65)	51.45	1.49	1.46	1.48	41.87

<i>T. harzianum</i> + <i>P. fluorescens</i> (ST @ 4+4 gm/kg seed and SA- 2.5+2.5 kg/ha.) without vermicompost	17.67 (24.52)	18.92 (25.78)	18.29 (25.15)	58.86	1.63	1.61	1.62	47.02
<i>T. harzianum</i> (ST @ 8 gm/kg seed and SA- 5 kg/ha.) without vermicompost	22.25 (28.12)	26.43 (30.94)	24.34 (29.53)	45.25	1.36	1.32	1.34	36.10
Control (without bioagents treatment)	42.75 (40.83)	46.17 (42.80)	44.46 (41.82)		0.90	0.82	0.86	
S.E.m. $\pm$	(1.33)	(0.76)	(0.76)		0.01	0.02	0.01	
C.D (p=0.05)	(3.98)	(2.28)	(2.20)		0.04	0.06	0.04	

* Figures in parentheses are angular transformed values. Note: ST- Seed treatment, SA- Soil application

The shoot and root lengths of cumin plants was significantly increased in response to bioagent treatments. Highest shoot and root lengths were recorded in combined bioagent treatment with *T. harzianum* + *P. fluorescens* seed treatment (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) along with vermicompost followed by the combined use of bioagent treatment *T. harzianum* + *P. fluorescens* as a seed treatment (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) without vermicompost (table 2). The treatment *T. harzianum* + *P. fluorescens* seed treatment (4+4 gm/kg seed) and soil application along with vermicompost (2.5+2.5 kg/ha.) was statistically significant as compared to treatment *T. harzianum* + *P. fluorescens* seed treatment (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) without vermicompost and rest of the treatments. Both the shoot and root lengths of cumin plants were also positively influenced by the *T. harzianum* seed treatment (8 gm/kg seed) and soil application (5 kg/ha.) along with vermicompost, *P. fluorescens* seed treatment (8 gm/kg seed) and soil application (5 kg/ha.) used along with vermicompost and *T. harzianum* + *P. fluorescens* seed treatment (4+4 gm/kg seed).

Results also revealed that cumin seed yield was significantly enhanced in response to bioagent treatments as compare to control. Highest seed yield was recorded in the combined bioagent treatment *T. harzianum* + *P. fluorescens* as seed treatment (4+4 gm/kg seed) and soil application

(2.5+2.5 kg/ha.) along with vermicompost which was closely followed by seed treatment *T. harzianum* + *P. fluorescens* (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) without vermicompost and *T. harzianum* seed treatment (8 gm/kg seed) and soil application (5 kg/ha.) along with vermicompost (table 2). The seed yield recorded in combined bioagent treatment *T. harzianum* + *P. fluorescens* used as a seed treatment (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) along with vermicompost was statistically at par with the treatment *T. harzianum* + *P. fluorescens* seed treatment (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) without vermicompost. However, the combined bioagent *T. harzianum* + *P. fluorescens* seed treatment (4+4 gm/kg seed) and soil application (2.5+2.5 kg/ha.) along with vermicompost was statistically significant as compare with *T. harzianum* seed treatments (8 gm/kg seed) and soil application (5 kg/ha.) along with vermicompost treatment and all other treatments. Seed yield of cumin was also considerably higher in the bioagent treatments *P. fluorescens* seed treatment (8 gm/kg seed) and soil application (5 kg/ha.) along with vermicompost, alone seed treatment by *T. harzianum* + *P. fluorescens* (4+4 gm/kg seed) and *T. harzianum* seed treatment (8 gm/kg seed) and soil application (5 kg/ha.) without vermicompost as compare to all other treatments (Table 2).

Table 2. Effect of bioagents on shoot, root length and grain yield of cumin (Pooled 2013 and 14)

Treatments	Shoot length (cm)		Pooled	Root length (cm)		Pooled	Grain yield (q/ha)		Pooled
	2013-14	2014-15		2013-14	2014-15		2013-14	2014-15	
<i>T. harzianum</i> (ST @ 8 gm/kg seed)	26.33	22.37	24.35	13.23	11.77	12.50	3.63	3.89	3.76
<i>T. harzianum</i> (ST @ 8 gm/kg seed and SA- 5 kg/ha.) along with vermicompost	32.50	30.30	31.40	15.30	14.00	14.65	4.88	5.25	5.07
<i>T. harzianum</i> + <i>P. fluorescens</i> (ST @ 4+4 gm/kg seed)	29.97	26.00	27.98	14.00	12.70	13.35	4.21	4.83	4.52

<i>T. harzianum</i> + <i>P. fluorescens</i> (ST @ 4+4 gm/kg seed and SA- 2.5+2.5 kg/ha.) along with vermicompost	35.43	34.27	34.85	16.77	15.43	16.10	5.41	5.89	5.65
<i>P. fluorescens</i> (ST @ 8 gm/kg seed)	23.80	20.50	22.15	12.43	10.03	11.23	3.16	3.44	3.30
<i>P. fluorescens</i> (ST @ 8 gm/kg seed and SA- 5 kg/ha.) along with vermicompost	31.70	27.43	29.57	15.40	13.30	14.35	4.76	5.06	4.91
<i>T. harzianum</i> + <i>P. fluorescens</i> (ST @ 4+4 gm/kg seed and SA- 2.5+2.5 kg/ha.) without vermicompost	33.67	31.20	32.43	15.70	14.43	15.07	5.21	5.58	5.40
<i>T. harzianum</i> (ST @ 8 gm/kg seed and SA- 5 kg/ha.) without vermicompost	26.60	23.47	25.03	13.67	12.20	12.93	4.38	4.43	4.41
Control (without bioagents treatment)	19.83	17.60	18.72	8.50	7.30	7.90	2.83	3.50	3.17
S.E.m. ±	0.57	0.73	0.46	0.39	0.36	0.27	0.10	0.26	0.14
C.D (p=0.05)	1.71	2.20	1.34	1.18	1.08	0.77	0.30	0.77	0.40

Note: ST- Seed treatment, SA- Soil application

The antagonistic potentiality of *T. harzianum*, *T. viride*, *T. hamatum* and bacterial antagonists like *P. fluorescens*, *B. subtilis*, etc. against *F. oxysporum* pathogenic to cumin and many other host crops have been reported by several workers (Mukhopadhyay, 1987; Dubey *et al.*, 2007; Deepak *et al.*, 2008 and Khan and Gangopadhyay, 2012). The antagonistic effect of many bacterial antagonists like *P. fluorescens* and *B. subtilis* against different *Fusarium* spp. viz., *F. oxysporum* f. sp. *ciceri*, *F. oxysporum* f. sp. *udum*, *F. oxysporum* f. sp. *cubense*, *F. oxysporum* f. sp. *vasinfectum*, etc. was reported by many workers (Ushamalani *et al.*, 1997; Haq *et al.*, 2001 and Prameela *et al.*, 2005).

Godwin-Egein and Arinze (2001) concluded that growth inhibition of *F. oxysporum* by *T. harzianum* was due to competition, lysis and hyperparasitism. Besides, induction of systemic resistance by *Trichoderma* and *Pseudomonas* species against soil-borne pathogens have been reported (Van Loon *et al.*, 1998; Karthikeyan *et al.*, 2006 and Jayalakshmi *et al.*, 2009).

In another study, Yigit and Dikilitas (2007) tested the ability of biocontrol agents, fluorescent *Pseudomonas*, non-pathogen *Fusarium* strain and *T. harzianum* T-22 applied in combination and alone, to control of *F. oxysporum* f. sp. *lycopersici* was studied in the greenhouse. Tomato roots were treated with combination of *T. harzianum* T-22 + fluorescent *Pseudomonas* isolate gave the best control. Similarly, Garkoti, *et al.*, (2014) observed that seed treatment with *T. harzianum* + *P. fluorescens* significantly reduced the *Fusarium* wilt disease incidence of lentil and increase in grain yield. In field conditions, seed and soil treatment with *T. harzianum* and *P. fluorescens* were found to enhance the root/shoot length and seed yield.

In conclusion, the combined bioagent seed treatment and soil application by *T. harzianum* + *P. fluorescens* isolates along with vermicompost reduced wilt severity in cumin plants.

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Effect of fertility level and biofertilizers on seed yield and quality of cluster bean

B. M. Kalalbandi^{1*}, A. S. Lohakare² and P. N. Nanaware³

College of Horticulture, Vasantao Naik Marathwada Krishi Vidyapeeth, Parbhani

¹Assistant Professor, College of Horticulture, VNMKV, Parbhani 431 402 (MS)

³M.Sc. (Hort) Student, Department of Horticulture, VNMKV, Parbhani.

*Corresponding author email: kbaslingappa@yahoo.com

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Abstract

The field investigation was conducted to study the effect of fertility level and biofertilizers on seed yield and quality of cluster bean. On the basis of investigation, it was concluded that application of fertilizer level at 25:50 kg N:P/ha (F₃) found to be beneficial in recording seed yield and quality of cluster bean. As regard to the biofertilizers, application of rhizobium and PSB in combination was found to be beneficial in producing highest seed yield, straw yield and improved its quality i.e. gum content and viscosity profile as compared to rest of treatments. The interaction effect of fertility level and biofertilisers was significant for straw yield and biological yield.

Key words: *Guar gum, PSB, Rhizobium, and viscosity*

Introduction

Cluster bean (*Cyamopsis tetragonoloba* (L.) Taub) is commonly known as multipurpose, annual, legume vegetable. India is considered to be the centre of origin of cluster bean. India stands first in area and production i.e. 80% of total world (Anonymous, 2012). Seeds contain gum like mucilaginous substance called 'GUAR GUM' or galactomannan. It has various industrial applications due to some unique characteristics like grease resistant, thickening agent, capacity to bind water and high viscosity and functioning in low temperature. Due to which, it is used in multifarious, cosmetics, explosive, oil and mining industry, textile paper industries and also in dairy products like ice-cream, stabilizer in cheese. It is used as a glaze in candy products and in baking industry, (Raghu *et al*, 2008).

Materials and Methods

A field experiment was conducted at the field of Department of Horticulture, Vasantao Naik Marathwada Krishi Vidyapeeth, Parbhani during summer season of 2013-2014. The experiment was laid out in factorial randomised block design with three replication comprising three level of fertility [15:30 (F₁), 20:40 (F₂), 25:50 (F₃) kg N:P/ha] and four level of biofertilizers [control (B₀), Rhizobium (B₁), PSB (B₂), Rhizobium + PSB (B₃)] thereby involving twelve treatment combinations (table1) on cluster bean variety RGC- 936. The gross plot size was 3.6 m x 4.6 m and net plot size 2.7 m x 3.6 m, respectively.

Table 1. Details of treatment combination

Sr. No.	Treatment Details	
	Fertility level	Biofertilizers
T ₁	15:30 N:P kg/ha	[Control]
T ₂	15:30 N:P kg/ha	Rhizobium
T ₃	15:30 N:P kg/ha	PSB
T ₄	15:30 N:P kg/ha	Rhizobium + PSB
T ₅	20:40 N:P kg/ha	[Control]
T ₆	20:40 N:P kg/ha	Rhizobium
T ₇	20:40 N:P kg/ha	PSB
T ₈	20:40 N:P kg/ha	Rhizobium + PSB
T ₉	25:50 N:P kg/ha	[Control]
T ₁₀	25:50 N:P kg/ha	Rhizobium
T ₁₁	25:50 N:P kg/ha	PSB
T ₁₂	25:50 N:P kg/ha	Rhizobium + PSB

The weight of 1000 seed from each net plot was measured as the seed index expressed in grams. Five plants are taken for measuring seed yield per plant expressed in grams. At harvesting the threshing of plant of particular plots seed weighted and expressed in grams. Seed yield per hectare was calculated from seed yield per plot separately as for particular treatment, and expressed in kg per hectare. The harvested produce of each net plot was weight of produce was recorded as biological yield per net plot which was converted to in hectare basis, and expressed in kg per hectare. Straw yield was recorded by deducting the grain weight from the weight of total biological yield of respective net plot and also converted in to hectare basis. The guar gum or galactomanon have been isolated and purified by wet processing method at laboratory scale. The mature grains of cluster bean were cleaned and boiled in 2% alkali solution i. e. NaOH at 100^o C for 5-10 min to remove husk or hull portion. This was followed by washing the seed in running water, and neutralized with dilute acid (HCl) and again washing with water. Husk was removed and dried for night over. The grains were then pulverized to get gum splits. The splits were converted into powder known as crude gum. The crude gum was suspended in aqueous solution of iso-propanol and resultant precipitate was centrifuged at 5000 x for 15 min. The purified gum was vacuum dried and pulverized to 200-mesh size (Rodge *et al*, 2006). After extraction of gum (galactomanon), the viscosity profile was measured by "Brookfield's Viscometer" in laboratory.

Results and Discussion

The maximum 1000 seed weight (32.83 g) was recorded in treatment F₃ where 25:50 kg N:P/ha was applied, and which was at par with treatment F₂ (32.21) where fertilizer dose applied at 20:40 kg N:P/ha. The results are in agreement with Reddy and Reddy (2011) in cluster bean. The maximum 1000 seed weight (33.52 g) was recorded with application of both rhizobium and PSB. The treatment B₂ (PSB) and B₁ (rhizobium) are at par with each other. Jitender kumar (2011) was given similar type of result in pigeon pea. The interaction effect of fertility level and biofertilizers on seed index was found to be non-significant.

The maximum seed yield per plant (4.76 g) was observed with application of 25:50 kg N:P/ha. The treatments F₃ and F₂ were significantly superior over treatment F₁ (3.56 g) where fertilizer dose was applied 15:30 kg N:P/ha. This result was in confirmation with Yadav *et al* (2012) in cluster bean. Whereas the maximum seed yield per plant (4.81g) was recorded with application of rhizobium + PSB, which was significantly superior over B₀ (3.71g) where no bio-fertilizers were used. The treatments B₁

(rhizobium) and B₂ (PSB) were at par with each others. The interaction effect of fertility level and biofertilizers on seed yield per plant was found non-significant.

The application of fertilizer dose at 25:50 kg N:P/ha produced maximum seed yield per hectare (792.31 kg/ha), which was at par with treatment F₂ (701.95 kg/ha). The present findings are in accordance with results of Saxena and Verma (1995) and Reddy and Reddy (2011) in cluster bean. Similarly the biofertilizers significantly influenced the seed yield per hectare. The treatment B₃ (rhizobium + PSB) recorded maximum seed yield per hectare (800.48 kg/ha) over all other treatments. The application of rhizobium and PSB were at par with each other. Kumpawat (2006) reported similar results in cluster bean. The interaction effect between fertility level and biofertilizers for seed yield per hectare was found to be significant. The maximum seed yield per hectare (902.63 kg/ha) was observed in treatment F₃B₃ (25:50 kg N:P/ha + rhizobium + PSB). While minimum was observed in treatment F₁B₀. The result shown that, seed yield per hectare decreased with reduced fertility levels. Similar results were recorded by Patel *et al* (2009) in cluster bean.

The maximum straw yield per hectare was recorded with treatment F₃ (1635.41 kg/ha) where the fertilizer dose was applied at 25:50 kg N:P /ha, which was at par with treatment F₂ (1516.13 kg/ha) in which fertilizer dose was applied at 20:40 kg N:P/ha. Kumawat *et al* (2006) in cluster bean also found similar results supports present findings. Application of biofertilizers significantly influenced the straw yield per hectare. The maximum straw yield per hectare was obtained in treatment B₃ (1701.72 kg/ha) where both rhizobium and PSB were used for seed inoculation of crop over rest of biofertilizer treatments under study. The treatment B₂ (PSB) and B₁ (rhizobium) were statistically at par with each other. Similar results were reported by Meena *et al* (2003) in cluster bean. The interaction effect between fertility level and biofertilizers was found significant for straw yield per hectare. The maximum straw yield per hectare (1824.69 kg/ha) was recorded in treatment F₃B₃ (25:50 kg N:P/ha + rhizobium + PSB). The minimum straw yield per hectare (1197.46 kg/ha) was found in treatment F₁ B₀ (15:30 kg N:P/ha.). Present result was in close proximity with result of Tanwar *et al* (2003) in black gram.

The biological yield per hectare was found maximum in treatment F₃ (2406.12 kg/ha) where the fertilizer dose was applied at 25:50 kg N:P per hectare. The treatment F₃ was at par with treatment F₂ (2198.96 kg/ha). Meena *et al* (2003) reported similar results in cluster bean. The maximum biological yield was recorded in treatment B₃ (2480.40 kg/ha) where both rhizobium and PSB was used. The treatment B₁ (rhizobium) was at par with treatment B₂

(PSB). These results are on similar track with Sammauria *et al* (2009) in cluster bean. The interaction effect between fertility levels and biofertilizers for biological yield were found significant. The maximum biological yield was found in treatment F₃B₃ (2702.73 kg/ha). The minimum biological yield (1704.52 kg/ha) was observed in treatment F₁B₀ where fertilizer dose applied at 15:30 kg N:P/ha with no use of any biofertilizers.

The maximum gum content (28.29 %) was recorded in treatment F₃ (25:50 kg N:P/ha), which was at par with treatment F₂ (27.97%). These findings are in accordance with Ramawtar *et al* (2013) in cluster bean. The data revealed that the maximum gum content (28.84 %) was recorded in treatment B₃ where both rhizobium + PSB were used. The treatment B₂ (27.95 %) and B₁ (27.60 %) were at

par with each others. Similar results are found by Rathore *et al* (2007) in cluster bean. The interaction effect of fertility level and biofertilizer on gum content of cluster bean seed was found to be non-significant.

The viscosity profile of gum refers to the quality guar gum, which was influenced by application of fertility level. The maximum viscosity of gum (3251.99 cp) found with treatment F₃ (25:50 kg N:P/ha). The maximum viscosity profile (3228.59 cp) was recorded in treatment B₃ (rhizobium + PSB). The treatments B₃, B₂ and B₁ were significantly superior over treatment B₀ (3132.47 cp) where any biofertilizer was not used. The interaction effect of fertility level and biofertilizer on viscosity of gum of cluster bean seed was found to be non-significant.

Table 2. Seed yield and quality of cluster bean as influenced by fertility level and biofertilizers

FXB	1000 Seed weight (g)	Seed yield (g/plant)	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Gum content (%)	Viscosity profile of gum (cp)
Fertility level (F)							
F ₁	29.63	3.56	592.04	1364.49	1940.40	26.60	3099.93
F ₂	32.21	4.22	701.95	1516.13	2198.96	27.97	3178.98
F ₃	32.83	4.76	792.30	1635.41	2406.12	28.28	3251.99
SEm ±	0.52	0.22	32.94	42.02	85.84	0.41	50.09
CD (at 5%)	1.52	0.64	95.76	122.85	254.10	1.20	148.52
Biofertilizers (B)							
B ₀	28.61	3.71	618.41	1298.82	1900.38	26.06	3132.47
B ₁	31.34	4.01	667.25	1450.66	2099.74	27.60	3150.66
B ₂	32.95	4.18	695.57	1570.17	2246.79	27.95	3196.13
B ₃	33.32	4.81	800.48	1701.72	2480.40	28.84	3228.59
SEm ±	0.59	0.24	36.89	48.52	90.34	0.49	52.01
CD (at 5%)	1.76	0.71	107.39	142.31	266.78	1.43	154.27

Table 3. Seed yield and quality of cluster bean as influenced by interaction effect of fertility level and biofertilizers

(FXB)	1000 Seed weight (g)	Seed yield (g/plant)	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Gum content (%)	Viscosity of gum (cp)
F ₁ x B ₀	26.54	3.13	521.26	1197.46	1704.52	25.13	3062.7
F ₁ x B ₁	29.40	3.36	559.56	1287.27	1831.59	26.74	3077.35
F ₁ x B ₂	31.08	3.53	587.87	1402.91	1974.77	27.02	3114.35
F ₁ x B ₃	31.5	4.20	699.45	1570.31	2250.71	27.5	3145.7
F ₂ x B ₀	29.24	3.83	632.84	1305.76	1921.36	26.39	3125.73
F ₂ x B ₁	32.03	4.06	676.14	1457.76	2115.48	27.83	3162.54
F ₂ x B ₂	33.65	4.22	699.45	1590.86	2271.26	28.44	3200.2
F ₂ x B ₃	33.93	4.81	799.37	1710.15	2487.75	29.21	3227.5
F ₃ x B ₀	30.06	4.21	701.12	1393.24	2075.26	26.66	3209.02
F ₃ x B ₁	32.58	4.60	766.07	1606.96	2352.16	28.24	3212.1
F ₃ x B ₂	34.13	4.80	799.37	1716.74	2494.34	28.38	3274.1
F ₃ x B ₃	34.54	5.42	902.63	1824.69	2702.73	29.82	3312.58
SEm ±	1.02	0.45	65.87	84.02	169.68	0.82	101.2
CD (at 5%)	NS	NS	191.51	245.05	498.96	2.41	292.03

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Foraging behaviour of insect pollinators on coriander

Harjindra Singh^{1*}, R. Swaminathan¹ and S. M. Haldhar²

¹Department of Entomology, Rajasthan College of Agriculture, Udaipur, Rajasthan,

²Central Institute for Arid Horticulture, Bikaner

*Corresponding Author email: jindra.ento@gmail.com

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Abstract

The major insect pollinators included Hymenoptera, Diptera, a few Lepidoptera, Hemiptera and Coleoptera. Among these, the mean of total hymenopterans visiting the umbels of coriander during the entire flowering period happened to be 18.89/plant/minute-observation/day; within hymenopterans, *A. florea* and *A. dorsata* were the most dominant forming 91.54 per cent. The foraging activity of *A. florea* was more pronounced during 12-2 p.m. (1.312 bees/ day/ plant/ minute observation), whereas the foraging activity of *A. dorsata* was maximum during 8-10 a.m. (0.032 bees/ day/ plant/ minute observation). *A. florea* formed 38.86 (8-10 a.m.), 86.36 (12-2 p.m.) and 27.43 (4-6 p.m.) per cent of the total insect pollinators, the corresponding figures for *A. dorsata* were 9.35 (8-10 a.m.), 1.18 (12-2 p.m.), and 2.26 (4-6 p.m.) per cent. The total dipterans that visited the umbels of coriander during the entire flowering period happened to be 0.36-flies/plant/minute/day. The family Muscidae was most dominant with 0.26-flies/plant/minute/day. The foraging activity of muscid flies was the maximum during 4-6 p.m. (0.094-flies/ plant/minute/day) forming 26.70 per cent. Otherwise too, Dipterans happened to be the maximum during 4-6 p.m. (0.061-flies/plant/minute/day) followed by that at 8-10 a.m. (0.035-flies/plant/minutes/day). The other insect pollinators included insects of Lepidoptera, Hemiptera and Coleoptera and their numerical abundance formed 0.107-insects/plant/minute/day. Of these, hemipteran visitors dominated with 0.091-bugs/plant/minute/day. The foraging activity of Hemiptera was the maximum during 4-6 p.m. (10.01%) and minimum during 12-2 p.m. (1.98%). On the basis of the seven class-interval categories that could be identified, most insect pollinators happened to fall under the category of 1-5 insects per unit of observation.

Key words: Coriander, insect pollinators, diversity, foraging behaviour

Introduction

Coriander (*Coriandrum sativum* L.) is a classic example having xygomorphic flowers, the flower having reduced five sepals, petals, stamens and inferior ovaries consisting of two chambers, each containing one ovule. Stylopodium surrounds the ovaries around which nectar is secreted and two short styles emerge from the centre of the disc. Although the flowers are self-fertile the protandrous condition prevents self-pollination (McGregor 1976). Nearly 300000 plant species and over 200000 insect species and vertebrates are involved in interdependent plant-pollinator interactions worldwide (NRC, 2007). Diverse pollinator assemblages can lead to improved ecosystem function through enhanced pollination services, plant reproduction (Fontaine *et al.*, 2006). Insect pollination results in significant crop yield and also improves the fruit quality. Honey bees and some other closely related social Hymenoptera, having nectar and pollen as the only source of their food, while foraging fortuitously reciprocate by performing valuable pollination services. The important insect pollinator genera include: honey bees, solitary bees,

bumble bees, stingless bees and many kinds of flies, beetles, black ants, thrips and moths. Among insects, the members of the super-family Apoidea (Hymenoptera) are the most important pollinators. Of the 95 per cent cross pollinated flowers, 85 per cent depend on insect pollination (Carruth, 1950); and bees are responsible for almost 80 per cent of the pollination services. Another benefit of coriander derives from the reproductive biology of this plant, as coriander produces a considerable quantity of nectar and thereby attracts many different insects for pollination, an external effect which is of both ecological and economic value; hence, is also a good melliferous plant (Luk'janov and Reznikov, 1976) with the ability of obtaining 500 kg of honey from one hectare of coriander. Keeping these points in view, studies were carried out to study the diversity of insect pollinators visiting coriander.

Materials and Methods

The study on diversity of insect pollinators on coriander was conducted at the Department of Entomology, Rajasthan College of Agriculture, Udaipur. The crop of

coriander was cultivated at the Instructional Farm of the College. The land was prepared by ploughing with the help of tractor mounted mould board plough 15 days before sowing the crop and just before sowing the land was again ploughed and leveled with the help of a heavy plank. Half of the recommended dose of nitrogenous fertilizers (60 kg/ha) and full dose of phosphatic (40 kg/ha) and potassic (25 kg/ha) fertilizers were applied at the time of last ploughing and the rest of the nitrogenous fertilizer was applied through top dressing at the time of flowering. Coriander variety "RCR-41" was cultivated; before sowing the seeds were crushed into halves by gently rubbing between palms and treated with Thiram and Bavistin in the portion of 1: 1 @ 2 g/kg seed. Sowing was done by manually operated hand driven plough maintaining the row to row distance of 30 cm with a seed rate of 10 kg/ha. During the crop period five irrigations were given at an interval of 20 – 25 days. The first irrigation was applied just after sowing. Thinning was done 30 days after sowing keeping the plant to plant distance at 10 cm. Weeding was done twice after first and second irrigation respectively. Other recommended agronomical practices were followed as and when needed.

A replicated trial was conducted to estimate the diversity of insect pollinators of coriander, for this 5 plants from one plot were selected at random, tagged for observing the pollinators at flowering and records were made from 7 such plots (3 × 2 meter²). Insect pollinators were recorded at three different periods of the day {morning (8-10 a.m.), afternoon (12-2 p.m.) and evening (4-6 p.m.)}. The duration of each observation to record the pollinators was one minute per tagged plant. While taking observations, the total number of insects that visited during each observational period was noted; besides, the hymenopterans and dipterans were categorized. The data on insect pollinators (total, order-wise and species-wise) were correlated with the abiotic factors of the environment (average atmospheric temperature, relative humidity and wind velocity). The species richness and abundance was estimated and expressed as a percentage. The diversity indices (Shanon-Weiner and Simpson) were calculated to establish the species' numerical abundance for each observational period separately.

$$\text{Shannon - Weiner Diversity Index} = -\sum (p_i) \log p_i$$

$$\text{Simpson Diversity Index} = \sum (p_i)^2 / N$$

Results

The insect pollinator diversity recorded during the flowering period on coriander included insects belonging to the orders Hymenoptera, Diptera, Hemiptera, Coleoptera and Lepidoptera; however, the dominant pollinators represented Hymenoptera and Diptera. Observations were taken from 5 plants, selected at random, and from 7 such

replications totaling to 35 plants as the sample unit, and have been expressed accordingly. Careful observation was made to note the activity of the hemipteran pollinators so as to ascertain whether they caused any damage to the floral parts or manifested pollination by chance.

From Table (1) on relative intensity of hymenopteran pollinators visiting coriander during 2008-09, it can be observed that the total hymenopterans that visited the umbels of coriander during the entire flowering period summed up to a total of 3060 per 35 observed plants; wherein, each plant was observed for a one-minute duration. Among the hymenopterans, *A. florea* and *A. dorsata* were the most dominant forming 91.54 percent of the total hymenopterans. The foraging activity of *A. florea* was recorded to be the maximum during 12-2 p.m. with an average of 45.94 bees visiting per day on the 35 plants observed for 1 minute on each plant; whereas, the foraging activity of *A. dorsata* was the maximum during 8-10 a.m. (1.12 bees visiting per day on the 35 plants observed for 1 minute on each plant). However, *A. florea* was also noted to forage during 8-10 a.m. (4.64 bees per day on the 35 plants observed for 1 minute on each plant) and 4-6 p.m. (3.42 bees per day on the 35 plants observed for 1 minute on each plant). Similarly, *A. dorsata* also foraged during 12-2 p.m. (0.62 bees per day on the 35 plants observed for 1 minute on each plant) and also during 4-6 p.m. (0.28 bees per day on the observed 35 plants). The maximum numbers of total hymenopteran pollinators were recorded during 12-2 p.m. (2456 per 35 observed plants during the entire flowering period for 1 minute on each plant) and minimum during 4-6 p.m. (274 per 35 observed plants during the entire flowering period for 1 minute on each plant). The maximum seasonal mean of hymenopteran pollinators at bloom was observed for *A. florea* during 12-2 p.m. (45.94), while maximum seasonal mean for *A. dorsata* was observed during 8-10 a.m. (1.12). On the basis of proportion of hymenopterous species, *A. florea* was the most dominant foraging species during 12-2 p.m. (93.52%), followed by that at 8-10 a.m. (70.30%) and minimum at 4-6 p.m. (62.41%). The bee, *A. dorsata* was observed to be proportionally the maximum during 8-10 a.m. (16.76%), followed by that at 4-6 p.m. (5.11%); thereafter, 1.26 per cent during 12-2 p.m. The Shannon-Weiner Diversity Index for the hymenopteran pollinators was the maximum during 8-10 a.m. and 4-6 p.m. (being 0.811 at both times). The diversity index was the lowest during 12-2 p.m. (0.284). Similarly, the Simpson Index showed maximum diversity of hymenopteran pollinators during 4-6 p.m. (6.03) followed by that during 8-10 a.m. (5.56) and the lowest during 12-2 p.m. (3.42).

The frequency of hymenopteran pollinators visiting coriander umbels at different hours of the day has been presented in Table: 1 (A). The data obtained on frequency of visits by different hymenopteran species has been expressed on a number basis as well as in percentage. The frequency

of visit by the insect pollinators was analyzed within 7 different class-intervals, i.e., 1-5; 6-10; 11-15; 16-20; 21-25; 26-30 and more than 31 bees/ other hymenopterans per unit of observation (35 plants, each plant having been observed for 1 minute). Accordingly, it could be observed that in the morning during 8 to 10 a.m., irrespective of the species of hymenopteran visiting coriander, the class-interval with 1-5 insects/ unit of observation had the maximum frequency (*A. florea* – 50%; *A. dorsata* – 82% and other hymenopterans – 86.7%). During 12 to 2 p.m., the class-interval of 1-5 insects/ unit of observation showed the maximum frequency for *A. dorsata* (94.1%) and other hymenopterans (58.3%); however, the class-interval with more than 31 insects/ unit of observation had the maximum frequency only for *A. florea* (69.4%). In the evening hours of the day (4 to 6 p.m.), the class-interval with 1-5 insects/ unit of observation indicated the maximum frequency (*A. florea* – 47.8%; *A. dorsata* – 100% and other hymenopterans – 73.7%); nevertheless, the class-intervals with 6-10 insects and 11-15 insects per unit of observation evinced a moderately good frequency of hymenopteran pollinator visits (*A. florea* – 17.4 & 21.7% and the other hymenopterans 15.8 & 5.2%, respectively).

From Table (2) showing the relative intensity of dipteran pollinators visiting coriander, it could be observed that the total dipterans that visited the umbels of coriander during the entire flowering period accrued to 628.34 per 35 observed plants for 1 minute duration on each plant. Among the total dipterans, flies of Muscidae family were the most dominant (72.31%). The foraging activity of muscid flies was the maximum during 4-6 p.m. (3.304 flies per day per minute on the 35 observed plants). The population of syrphid flies was the maximum during 8-10 a.m. (0.08 flies per day per minute on the 35 plants observed). The other unidentified dipteran pollinators were more (Total - 168) in comparison to syrphid flies (Total - 6) and these dipterans were the maximum during 4-6 p.m. (2.14 per day per minute on the 35 plants) followed by that during 8-10 a.m. (1.22 per day per minute observation on the 35 plants). Similarly, the seasonal mean for the flies of Muscidae was the maximum during 4-6 p.m. (3.30). The maximum proportion of flies (Muscidae) was during 12-2 p.m. (99.66%). As observed from the Table 2, the Shannon-Weiner Diversity Index was the maximum during 4-6 p.m. (0.6135) and minimum during 12-2 p.m. (0.017), while the Simpson Diversity Index was the maximum during 4-6 p.m. (7.62), followed by that during 8-10 a.m. (3.96) and lowest during 12-2 p.m. (3.02). Based on the class-interval analysis [Table: 2 (A)] the frequency of dipterans including Muscids, Syrphids and others happened to be almost 100 per cent in the class-interval of 1-5 insects per unit of observation at the different periods of the day observed; however, during 4 to 6 p.m. the class-interval with 6-10 insects per unit of observation showed a frequency of 16 per cent.

The other insect pollinators that included Lepidoptera, Hemiptera and Coleoptera (Table: 3), that visited the umbels of coriander during the entire flowering period accrued to 188 per 35 observed plants. Careful observations indicated that none of these visitors caused any visible symptoms of damage to the floral parts of coriander or the crop as a whole. Among the pollinators other than hymenopterans and dipterans, the hemipterans dominated with 85.11 per cent during the day. The foraging activity of Hemiptera was the maximum during 4-6 p.m. (1.24 bugs per day per minute on the 35 observed plants totaling 62 bugs) and minimum during 8-10 a.m. (0.9 per day per minute on the 35 observed plants). Lepidoptera was also maximum at 4-6 p.m. (a total of 6 per 35 observed plants during the entire flowering period) and minimum at 8-10 a.m. (a total of 2 per 35 observed plants during the entire flowering period); whereas, Coleoptera was maximum during 12-2 p.m. (a total of 9 per 35 observed plants during the entire flowering period) and minimum during 8-10 a.m. (a total of 2 per 35 observed plants). The maximum mean pollinator population, other than hymenopterans and dipterans, was for Hemiptera during 4-6 p.m. (1.24 per 35 observed plants per minute) and minimum during 8-10 a.m. (0.9 per 35 observed plants per minute). Within the hemipterans, the maximum proportion was recorded during 8-10 a.m. (91.84%) and minimum during 12-2 p.m. (80.30%). The maximum diversity of insect pollinators other than hymenopterans and dipterans as indicated by Shannon-Weiner Index was during 12-2 p.m. (0.617) and minimum during 8-10 a.m. (0.339). Similarly, the maximum diversity as indicated by Simpson Diversity Index was during 12-2 p.m. (4.49).

From the Table 3 (A), the frequency of insects pollinators of other orders excluding Hymenoptera and Diptera, showed the dominance of the class-interval with 1-5 insects per unit of observation at all hours of the day thereby indicating the number of pollinators per unit did not exceed 5. However, the frequency of visit by hemipterans happened to fall in the class-interval of 6-10 insects per unit of observation during 8 to 10 a.m. and in the class-interval of 6-10 and more than 11 insects per unit of observation at 12-2 p.m.

Discussion

During the present investigation, the insect pollinators that were observed to visit coriander crop included hymenopterans, dipterans, a few Lepidoptera, Hemiptera and Coleoptera; and based on the significant numbers in which they were recorded, they could be considered as the major insect pollinators. Among these, the mean total hymenopterans visiting the umbels of coriander during the entire flowering period happened to be 18.89/plant/minute-observation/day.

Among hymenopterans, *A. florea* and *A. dorsata* were the most dominant forming 91.54 per cent. The foraging activity of *A.*

florea was more pronounced during 12-2 p.m. (1.312 bees/ day/ plant/ minute observation), whereas the foraging activity of *A. dorsata* was maximum during 8-10 a.m. (0.032 bees/ day/ plant/ minute observation). While *A. florea* formed 38.86 (8-10 a.m.), 86.36 (12-2 p.m.) and 27.43 (4-6 p.m.) per cent of the total insect pollinators, the corresponding figures for *A. dorsata* were 9.35 (8-10 a.m.), 1.18 (12-2 p.m.), and 2.26 (4-6 p.m.) per cent. Similar studies on coriander could not become available from the literature; however, Mahy *et al.* (1998) recorded the dominance of insects of Hymenoptera, Diptera and Lepidoptera in the pollination system of *Calluna vulgaris*, among which honeybees and bumble bees were the most efficient pollinators while syrphid flies were important co-pollinators. Kapila *et al.* (2002) recorded bees (69.29%) as a dominant group of insect pollinators on radish, followed by Dipterans and other insects collectively. Kuberappa *et al.* (2007) recorded 10 species of insect pollinators on *Vishnu tulsi* (*O. sanctum*) belonging to order Hymenoptera and Diptera. The mean abundance of *A. florea* (8.82/plant/5 minutes) was higher compared to *A. dorsata* (8.52/plant/5 minutes) and *A. cerana* (6.85/plant/5 minutes).

In the present study, the total dipterans that visited the umbels of coriander during the entire flowering period happened to be 0.36-flies/plant/minute/day. Of all the dipterans, the family Muscidae was most dominant with 0.26-flies/plant/minutes/day. The foraging activity of Muscidae flies was the maximum during 4-6 p.m. (0.094-flies/ plant/minute/day) forming 26.70 per cent. Otherwise to Dipterans happened to be the maximum during 4-6 p.m. (0.061-flies/plant/minute/day) followed by that during 8-10 a.m. (0.035-flies/plant/minutes/day). Other insect pollinators

included Lepidoptera, Hemiptera and Coleoptera and their numerical abundance formed 0.107-insects/plant/minute/day. Of these, hemipteran visitors dominated with 0.091-bugs/plant/minute/day. The foraging activity of Hemiptera happened to be the maximum during 4-6 p.m. (10.01%) and minimum during 12-2 p.m. (1.98%). The earlier work done clearly depicts the dominance of hymenopterans and dipterans as pollinators and more so of honeybees. The earlier work done clearly depicts the dominance of hymenopterans and dipterans as pollinators and more so of honeybees (Hafeez and Kotwal, 1996; Sachdeva *et al.*, 2003; Faria-Junior *et al.*, 2008).

The analysis of frequency of insect pollinators visiting coriander umbels at different hours of the day showed that the hymenopterans, dipterans and insects of other groups (Lepidoptera, Hemiptera and Coleoptera) happened to fall in the class-interval with 1-5 insects per unit of observation. This clearly indicated that per unit of observation there were not more than 5 insects visiting each minute observed. However, among hymenopterans, more than 31 insects per unit of observation were recorded for the dwarf honeybee, *A. florea* at 12 to 2 p.m. (Fig. 1). In a similar manner, among the insect pollinators of other orders, hemipterans were recorded to be in the class-intervals of 6-10 and more than 11 insects per unit of observation. It could be deduced that on coriander, at any given moment per unit of umbels, the number of insect visitors did not exceed more than 5, except in the case of *Apis florea* Fabricius and some other hymenopterans during mid-day (12-2 p.m.). Such an observation could be due to the more congenial atmospheric temperature for the bees/ hymenopterans during February-March season.

Table 1. Relative intensity of hymenopteran pollinators visiting coriander (*Coriandrum sativum* L.)

Parameters	8:00-10:00am			12:00-2:00pm			4:00-6:00pm		
	Apis. florea	Apis dorsata	Others	Apis florea	Apis dorsata	Others	Apis florea	Apis dorsata	Others
Sub.-total	232	56	42	2297	31	128	171	14	89
Total	330			2456			274		
Mean	4.64	1.12	0.84	45.94	0.62	2.56	3.42	0.28	1.78
Proportion (%)	70.30	16.96	12.73	93.52	1.26	5.21	62.41	5.11	32.48
Shanon-Weiner D.I. = $\sum \ln p_i \cdot p_i$	0.811			0.284			0.811		
Simpson D.I. (p_i^2/N)	5.56			3.42			6.03		

Note: Population intensity values are a total count from 35 plants (5-plants x 7-replications)

Table 1(A). Frequency of hymenopteran pollinators visiting coriander at different population densities during different hours of the day

Class intervals for population density	Period of major insect pollinator visits								
	8:00 to 10:00			12:00 to 2:00			4:00 to 6:00		
	<i>A. florea</i>	<i>A. dorsata</i>	Others	<i>A. florea</i>	<i>A. dorsata</i>	Others	<i>A. florea</i>	<i>A. dorsata</i>	Others
1-5	16 (50.00)	14 (82.00)	13 (86.70)	1 (2.00)	16 (94.10)	14 (58.30)	11 (47.80)	9 (100.00)	14 (73.70)
6-10	8 (25.00)	3 (9.40)	2 (13.30)	3 (6.12)	1 (5.90)	8 (33.30)	4 (17.40)	-	3 (15.80)

11-15	6 (18.75)	-	-	2 (4.08)	-	2 (8.30)	5 (21.70)	-	1 (5.20)
16-20	2 (6.25)	-	-	2 (4.08)	-	-	2 (8.70)	-	1 (5.20)
21-25	-	-	-	4 (8.16)	-	-	1 (4.30)	-	-
26-30	-	-	-	3 (6.12)	-	-	-	-	-
> 31	-	-	-	34 (69.40)	-	-	-	-	-
Total	32	17	15	49	17	24	23	9	19

Note: Figures in parentheses are corresponding per cent values

Table 2. Relative intensity of dipteran pollinators visiting coriander (*Coriandrum sativum* L.)

Parameters	8:00-10:00am			12:00-2:00pm			4:00-6:00 pm		
	Muscidae	Syrphidae	Others	Muscidae	Syrphidae	Others	Muscidae	Syrphidae	Others
Sub.-total	153.20	4.0	61.0	135.94	1.0	0.0	165.20	1.0	107.0
Total	218.20			136.94			273.20		
Mean	3.064	0.08	1.22	2.7188	0.02	-	3.304	0.02	2.14
Proportion (%)	70.21	0.66	10.07	99.66	0.23	0.00	60.47	0.16	16.72
Shannon-Weiner D.I. = $-\sum p_i \ln p_i$	0.5126			0.017			0.6135		
Simpson D.I. = $\sum p_i^2 / N$	5.96			3.02			7.62		

Note: Population intensity values are a total count from 35 plants (5-plants x 7-replications)

Table 2 (A). Frequency of dipteran pollinators visiting coriander at different class intervals

Class intervals for population density	Period of major insect pollinator visits								
	8:00-10:00a.m.			12:00-2:00p.m.			4:00-6:00p.m.		
	Muscidae	Syrphidae	others	Muscidae	Syrphidae	Others	Muscidae	Syrphidae	Others
1-5	50 (100.00)	5 (100.00)	25 (100.00)	48 (96.00)	2 (100.00)	-	50 (100.00)	2 (100.00)	42 (84.00)
6-10	-	-	-	2 (4.00)	-	-	-	-	8 (16.00)
Total	50	5	25	50	2	-	50	2	50

Table 3. Relative intensity of other insect pollinators visiting coriander (*Coriandrum sativum* L.)

Parameters	8:00-10:00am			12:00-2:00pm			4:00-6:00 pm		
	L	H	C	L	H	C	L	H	C
Sub.-total	2.0	45.0	2.0	4.0	53.0	9.0	6.0	62.0	5.0
Total	49.0			66.0			73.0		
Mean	0.04	0.9	0.04	0.08	1.06	0.18	0.12	1.24	0.1
Proportion (%)	4.08	91.84	4.08	6.06	80.30	13.64	8.22	84.93	6.85
Shannon-Weiner D.I. = $-\sum p_i \ln p_i$	0.339			0.617			0.527		
Simpson D.I. = $\sum p_i^2 / N$	3.50			4.49			4.09		

Note: L – Lepidoptera, H - Hemiptera, C – Coleoptera; Population intensity values are a total count from 35 plants (5-plants x 7-replications)

Table 3 (A). Frequency of other insect orders as pollinators visiting coriander at different class intervals

Class intervals for population density	Period of major insect pollinator visits								
	8:00-10:00a.m.			12:00-2:00p.m.			4:00-6:00p.m.		
	Lepidoptera	Hemiptera	Coleoptera	Lepidoptera	Hemiptera	Coleoptera	Lepidoptera	Hemiptera	Coleoptera
1-5	2 (100.00)	21 (95.50)	2 (100.00)	4 (100.00)	18 (85.70)	7 (100.00)	6 (100.00)	24 (88.90)	5 (100.00)

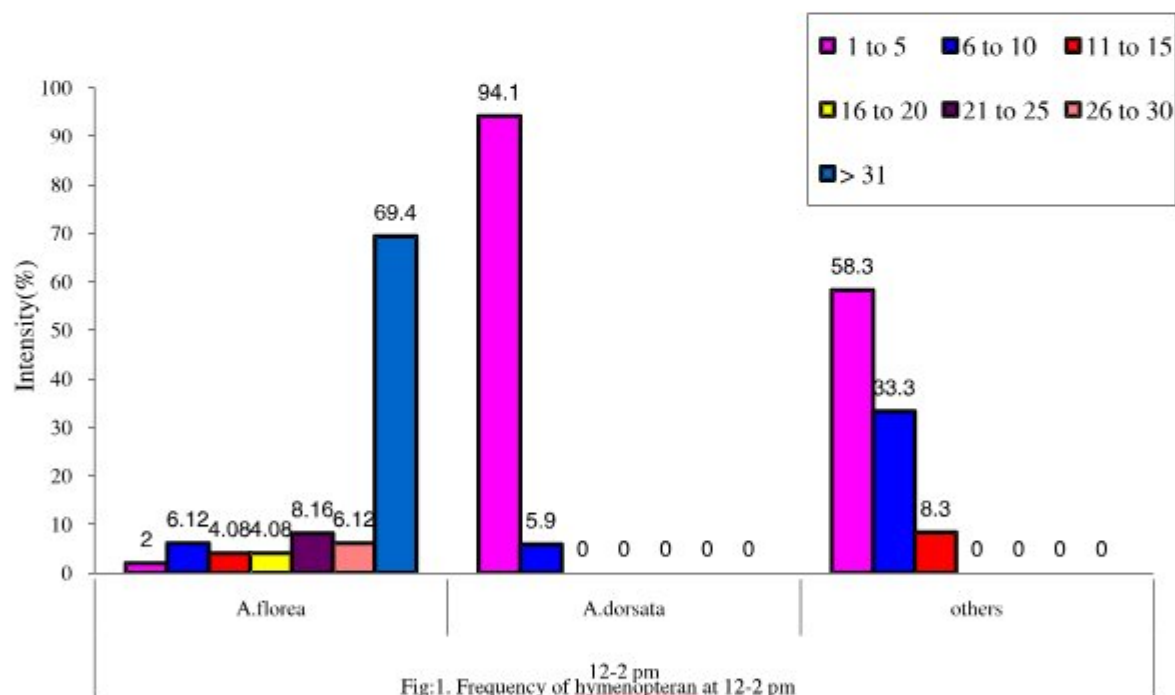
6-10	-	1 (4.50)	-	-	2 (9.50)	-	-	3 (11.10)	-
More than 11	-	-	-	-	1 (4.80)	-	-	-	-
Total	2	22	2	4	21	7	6	27	5

Note: Figures in parentheses are corresponding per cent values

Table 3 (B) Diversity of insect pollinators visiting coriander and their intensity at different hours of the day

Period of observation	Mean abiotic factors of the environment Temperature: 18.12°C; Relative Humidity: 58.16 %; Sunshine: 7.11 Hrs.; Wind Velocity: 2.16 Kmph								
	Major insect pollinators (Visits per plant/minute/day)								
	Hymenopterans			Dipterans			Other orders		
Foraging Period	<i>Apis florea</i>	<i>Apis dorsata</i>	Others	Muscidae	Syrphidae	Others	Lepidoptera	Hemiptera	Coleoptera
08:00 – 10:00 a.m.	0.133 (38.86)	0.032 (9.35)	0.024 (7.01)	0.088 (25.72)	0.0023 (0.67)	0.035 (10.23)	0.0011 (0.32)	0.0257 (7.51)	0.0011 (0.32)
12:00 – 02:00 p.m.	1.312 (86.36)	0.018 (1.18)	0.073 (4.81)	0.078 (5.13)	0.00057 (0.0375)	0.000 (Zero)	0.0022 (0.14)	0.0302 (1.98)	0.0051 (0.34)
04:00 – 06:00 p.m.	0.097 (27.43)	0.008 (2.26)	0.051 (14.42)	0.0944 (26.70)	0.00057 (0.16)	0.061 (17.25)	0.0034 (0.96)	0.0354 (10.01)	0.0028 (0.79)

Note: Figures in parentheses are corresponding per cent values



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Study on fruit growth and bunch characteristics in Date palm cultivars

Meena Kumari¹, R.S. Singh², R. Bhargava², P. K. Yadav¹ and B.D. Sharma²

¹Department. of Horticulture, SK Rajasthan Agric. Univ, Bikaner-334 006

²ICAR-Central Institute for Arid Horticulture, Bikaner-334 006 (Rajasthan)

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Abstract

The present study on fruit growth and bunch characters in Date palm (*Phoenix dactylifera* L.) cultivars under arid conditions was conducted at ICAR-Central Institute for Arid Horticulture, Bikaner during the year 2014. The treatments comprising of four date palm cultivars viz. Halawy, Khalas, Khadrawy and Shamran to assess morphological and bunch characteristics during fruit development. The study reveals that cultivar Halawy was earlier to attain *Kimri* stage after pollination whereas, Khadrawy requires maximum days. The fruit weight, length and diameter of fruit significantly increased from *kimri* to *doka* stage and harvesting. Fruit weight and diameter were found maximum in cv. Khalas (10.35 g and 2.28 cm, respectively) while fruit length was recorded maximum in cv. Halawy (3.45 cm).

The length of bunch varied from 44.76 cm (cv. Khadrawy) to 58.19 cm in cv. Shamran. The number of bunch/ tree was varied from 6.50 in cv. Khadrawy to 12.25 in cv. Khalas. The number of strands/ bunch was 35.50 and 79.50 for cv. Khadrawy and Halawy, respectively. The number of berries per strand varied from 16.50 in cv. Khalas to 21.50 in cv. Halawy. Length of strand was ranged from 33.50 cm and 45.75 cm in cv. Khadrawy and Shamran, respectively. A significant difference was noted in length of bunch, number of bunch, number of berries /strands and days taken to maturity of fruits. Days taken to colour turning stage, *doka* stage and harvesting of bunches were minimum in cv. Halawy (85, 103 and 110 days, respectively) while maximum days recorded in cv. Khadrawy (104, 118 and 123 days, respectively). The total soluble solids (TSS) increased significantly from initial fruit growth to *doka* stage of harvesting in date palm cultivars.

Key words: Date palm, *Phoenix dactylifera*, Cultivars, Fruit growth, Bunch characters

Introduction

Date palm (*Phoenix dactylifera* L. Family: Palmaceae) is one of most successful and extremely important subsistence fruit crop in hot arid regions of the world (Awad, 2011). In India, maximum area of date cultivation is about 17,072 ha with production of 1,37,476 million tonne in Kachchh region of Gujarat. Further, its cultivation has great potential in western parts of Rajasthan, which falls under hot arid climate and provided with irrigation facilities. Date palm is drought hardy fruit plant and tolerates salinity. Date fruit is used for fresh consumption as well as for value added products such as wine, starch vinegar, *arak*, jam, chutney, beverages, juice and toffees. It is highly nutritious fruit and contains high calorific value (3150 calories/kg of fresh fruits), 60-65% sugar, fair amount of fibre (2.5%), protein (2.0%), fat (2.0%), vitamins (vitamin A = 220 I.U., vitamin B₁ = 0.35 mg, vitamin B₂ = 0.38 mg), minerals up to (2.0%) i.e. iron, potassium, calcium, copper, magnesium, chlorine, sulphur, phosphorus, etc. (Gopalan *et al.*, 1985).

The date fruit goes through five distinct growth and ripening stages (Shobana *et al.*, 1981). These five stages are usually referred to in terms derived from Iraqi Arabic as

“Hababouk”, “Kimri”, “Khalal”, “Rutab” and “Tamer”. “Hababouk” stage which starts soon after fertilization and is characterized by loss of two unfertilized carpels. The *Kimri* or *gandora* represent the pea stage and immature green colour, *doka* or *Khalal* – mature full coloured and Rutab or *dang* -soft brown, Tamer or *pind*- hard raisin like (Chandra *et al.*, 1992). Under Indian conditions, maximum dates are harvested at hard ripen *doka* or *Khalal* stage due to early rains in July month.

The growth and development of the fruit follows a unique pattern in the date palm cultivars (Al-Qureshi and Adel, 2010). Although, work has been reported by different workers from different places which is mostly based on physical and chemical characters (Chandra *et al.*, 1992; Bacha *et al.*, 1987; Mertia *et al.*, 2010 and Markhand *et al.*, 2010). The present study was undertaken to assess the fruit growth and development patterns in date palm cultivars starting from *Kimri* to *doka* stage of maturity and bunch characteristics.

Material and Methods

The study was carried out at ICAR- Central Institute for Arid Horticulture Bikaner, Rajasthan in

Completely Randomized Design (CRD) with four replications. The four commercial date cultivars viz., Halawy, Khalas, Khadrawy and Shamran were taken for fruit growth and bunch characters study. The fruit samples were collected at 15 days interval (15th April, 30th April, 15th May, 30th May, 15th June, 30th June, 15th July and at harvesting) in the month of April to July 2014 for assessment of different morphological changes in fruit and bunch parameters of date palm cultivars. Five fruits sample from each treatment were taken randomly from four replications at fifteen days interval for record of weight and size of fruit. The fruit length and diameter of the fruit was measured with the help of digital Verneer calliper.

The length of bunch was measured by measuring scale from the origin of stalk to the end where the strands started appearing by selecting randomly three bunches from each tree were measured for the length of bunch in cm and mean value of each tree was taken into consideration for statistical analysis. Three stands were selected and the length of strand was measured and average length of strand was measured with the help of scale and averaged was presented in centimetres. Three strands were randomly selected from a bunch and number of berries in each strand was counted at the time of harvesting and then average number of fruits per strand was worked out. Number of strands were counted from randomly selected three bunches from which average number of strands per bunch was calculated. Days taken to colour turning stage from green to yellow was observed by counting the days from pollination to fruit set to colour turning stage in date palm cultivars. Days taken to *doka* stage were observed by counting the days from pollination to fruit set to *doka* stage. TSS was

measured by digital hand refractometer. Data obtained on various characters were analyzed statistically.

Results and Discussion

Periodic fruit growth data includes the weight, length and diameter of fruit is given in table-1, 2 and 3 respectively. Fruit weight, length and diameter increased from initial stage of fruit development to *doka* stage of maturity and significant variation among cultivars was observed during the study.

Weight of fruit (g)

The data presented in the table 1 showed the variation in fruit weight of different cultivars at fifteen days interval of fruit development. It revealed that the fruit weight was 7.33 g at harvesting stage which was 0.19 g at initial stage of fruit development in Halawy cultivars that gradually increased on 30th April to harvesting. On 30th April the magnitude of fruit weight was 1.05 g, which increased 3.29 g by 15th May. Maximum fruit weight was recorded in Khalas (10.35 g) followed by Khadrawy (7.81 g), Halawy (7.33 g) and lowest in Shamran (7.07 g). Difference among the cultivars in fruit weight was not significant at the initial stage of fruit development but significant at all other fruit development stages. Fruit weight, size, length and diameter were increased from *Kimri* stage of fruit growth to *doka* or *Khalal* stage followed by a slight decline in latter stages. The increase in size of fruit may possibly due to cell elongation and accumulation of biomass in fruits during growth and development period. The results are closely in conformity with findings of Shobana *et al.*, (1981); Bacha *et al.*, (1987); Chandra *et al.*, (1992) and Awad *et al.*, (2011).

Table 1. Weight of fruit (g) of different Date palm cultivars at 15 days interval

Treatments	April		May		June		July	Harvest
	15	30	15	30	15	30	15	
Halawy	0.19	1.05	3.29	4.67	6.62	6.72	7.22	7.33
Khalas	0.14	0.87	3.61	5.20	7.99	9.76	10.29	10.35
Khadrawy	0.28	0.96	3.39	5.11	7.22	7.47	7.60	7.81
Shamran	0.23	0.77	2.55	3.48	6.18	6.47	7.02	7.07
SEm±	0.04	0.06	0.18	0.32	0.26	0.68	0.74	0.52
CD (P=0.05)	NS	0.19	0.55	0.99	0.82	2.11	2.31	1.61

Length of fruit (cm)

The data in table 2 exhibited variations in the fruit length of different cultivars at fifteen days interval of fruit development except initial stage. The highest fruit length was recorded in Halawy (3.45 cm) followed by Khalas (3.33 cm), Shamran (3.25 cm) and lowest was in Khadrawy (3.07

cm). Difference among the cultivars was not significant at the initial stage of fruit development but significant at all other fruit development stages. The findings are similar to the results of Bacha *et al.*, (1987); Chandra *et al.*, (1992) and Awad *et al.*, (2011) reported in date palm cultivars.

Table 2. Length of fruit (cm) of different Date palm cultivars at 15 days interval

Treatments	April		May		June		July	Harvest
	15	30	15	30	15	30	15	
Halawy	0.82	1.31	2.31	3.04	3.17	3.33	3.42	3.45
Khalas	0.75	1.15	2.09	2.67	3.07	3.17	3.28	3.33
Khadrawy	0.68	1.10	1.77	2.52	2.88	2.93	3.07	3.07
Shamran	0.73	1.14	1.86	2.73	3.02	3.03	3.12	3.25
SEM±	0.04	0.04	0.09	0.08	0.03	0.05	0.06	0.06
CD (P=0.05)	NS	0.11	0.28	0.24	0.09	0.14	0.19	0.18

Diameter of fruit (cm)

Perusal of data from table 3 indicated the variation in fruit diameter of different cultivars at fifteen days interval of fruit development. From the table, it is revealed that the fruit diameter in date palm cultivar Halawy was 1.94 cm at harvesting stage which was 0.61 cm at initial stage of fruit development cultivars that gradually increased on 30th April

to harvesting. It was similar pattern in other cultivars. Highest fruit diameter was recorded in Khalas (2.28cm) followed by Khadrawy (2.22 cm), Shamran (2.10 cm) and lowest in Halawy (1.94 cm). Difference among the cultivars in diameter of fruits was found significant at all the fruit development stages. The finding is similar to the earlier report of Bacha et al,(1987) in date palm cultivars.

Table 3. Diameter of fruit (cm) of different Date palm cultivars at 15 days interval

Treatments	April		May		June		July	Harvest
	15	30	15	30	15	30	15	
Halawy	0.61	1.15	1.35	1.57	1.86	1.91	1.93	1.94
Khalas	0.54	1.05	1.47	1.72	2.03	2.21	2.26	2.28
Khadrawy	0.72	1.16	1.67	1.86	2.09	2.11	2.14	2.22
Shamran	0.65	1.12	1.44	1.65	1.86	1.94	2.04	2.10
SEM±	0.03	0.03	0.03	0.06	0.04	0.07	0.07	0.05
CD (P=0.05)	0.10	0.08	0.09	0.17	0.11	0.22	0.23	0.16

Bunch characteristics

Length of bunch (cm)

The highest bunch length was recorded in Shamran (58.19 cm), followed by Halawy (53.79 cm), Khalas (52.06 cm) and lowest bunch length was recorded in Khadrawy (44.76 cm) cultivar at harvesting stage(table-4). A significant difference in length of bunch was found in date palm cultivars at harvesting stage. The length of bunch varied among cultivars during the study. It might be due to age of palm, genetic makeup of the variety and environmental factors. The present findings are in conformity with the results of Chandra and Choudhary, (1992); Mertia *et al.*, (2010).

Number of bunch per tree

The maximum number of bunches were recorded in Khalas (12.25) cultivar followed by Halawy (9.0), Shamran (7.0) while minimum number of bunches recorded in Khadrawy (6.5) cultivar. Difference among the cultivars was significant at harvesting stage of bunches. The number of bunches per plant depends on the factors like age of tree, number of leaves/plant, cultural practices and growing site. The results are similar to the earlier findings of Mertia and Vashishtha (1985); Chandra and Choudhary, (1990).

Number of strands per bunch

The length of strands and number of berry are yield attributing characters in date palm crop. The maximum length of strand was recorded in Shamran (45.75 cm) cultivar followed by Khalas (41.00 cm), Halawy (38.75 cm) and minimum length of strand was recorded in Khadrawy (33.50 cm) cultivar. The observation recorded at harvesting shows that the maximum number of strands recorded in Halawy (79.50) cultivar followed by Khalas (61.75), Shamran (40.50) and minimum number of strands recorded in Khadrawy (35.50) cultivar. There was significant difference among cultivar in number of strands per bunch. The variation in number of strands per bunch was possibly due to genetic makeup of the cultivars and climatic conditions. The present finding is in conformity with the results of Chandra and Choudhary, (1992).

Number of berries per strand

The observation showed (table-4) that the maximum number of berries per strand recorded in cultivar Halawy (21.50) and at par in cultivars Khadrawy and Shamran (18.75), minimum in cv. Khalas (16.50). Difference among the cultivars in relation to berries per strand was significant at harvesting stages in date palm. The higher number of berries per strand might be due to length

of strand, high rate of fruit set and retention of fruit in a particular variety. Further, minimum number of berries /strand in cultivar Khalas may be due to poor fruit setting and drop of immature fruits. The result is similar to the earlier findings of Mertia *et al.*, (2010) while working on evaluation of date palm cultivars in Thar desert.

Days taken to colour turning stage

The maximum number of days in attaining the colour turning stage after pollination was counted in Khadrawy (104 days) followed by Shamran (99.00 days), Khalas (91.00 days) and minimum in case of Halawy (85.00 days) cultivar. Difference among the cultivars in relation to days to colour turning stage was significant at fruit development stages. The change in colour of fruits from green to yellow or reddish or dark red probably due to synthesis of pigments and degradation of chlorophylls. Bacha *et al.*, (1987) reported that pigments content being high at *Kimri* stage, were greatly reduced in other stages of fruit growth.

Days taken to *doka* stage of maturity and harvesting

The maximum number of days in attaining the *doka* stage of maturity after pollination was counted in Khadrawy (118.00 days) followed by Shamran (115.00 days), Khalas (108.00 days) and minimum in case of Halawy (103.00 days) cultivar (table 4). Difference in days taken for maturity among the cultivars was significant at *doka* stage. The difference in days taken for *doka* stage of maturity in date palm is possibly due to genetic features of the variety and climatic conditions. Similar findings have been reported by Mertia and Vashishtha, (1985) on the maturity of date fruits.

The maximum number of days in attaining the harvesting of bunches after pollination was counted in Khadrawy (123.00 days) followed by Shamran (120.00 days) and Khalas (115.00 days), while minimum days required in case of Halawy (110.00 days) cultivar. Difference among the cultivars was significant for days taken to harvest of bunch.

Total Soluble Solids (TSS ° Brix)

Perusal of data in table 5 shows an increase in TSS from *Kimri* stage to *doka* stage of harvesting. TSS slightly increased from 30th April to 15th June which rapidly increased from 30th June to full *doka* stage of harvesting possibly due to attaining full maturity and ripening. TSS of fruits in date palm cv. Halawy was 41.28 °Brix at harvesting stage which was 13.85 °Brix at initial stage of fruit development that gradually increased on 15th May to harvesting stage. The highest TSS content was recorded in Halawy (41.28 °Brix) followed by Khalas (39.17°Brix), Shamran (39.13°Brix) and lowest in Khadrawy (37.39 °Brix). A significant difference in TSS of fruits was recorded at fruit growth and harvesting stages. The findings are in agreement to the results reported by Bacha *et al*, 1987; Chandra *et al*, 199.

From the study, Halawy was found best in respect to fast fruit growth to attain early maturity, better fruiting and quality attributes. Halawy cultivar was superior over other cultivars in respect to minimum days taken to harvest, maximum fruit length, number of strands/bunch and number of berries per strand. However, cultivar Khalas was also found better than two other cultivars in respect to fruit growth, mid season maturity, more number of bunch/tree and higher fruit weight

Table 4. Bunch characteristics of different Date palm cultivars

Treatments	Length of bunch (cm)	No. of bunch/tree	No. of strands per bunch	Number of berries per strand	Days taken to colour turning stage	Days taken to <i>doka</i> stage of maturity	Days taken to harvesting of bunches
Halawy	53.79	9.00	79.50	21.50	85.00	103.00	110.00
Khalas	52.06	12.25	61.75	16.50	91.00	108.00	115.00
Khadrawy	44.76	6.50	35.50	18.75	104.00	118.00	123.00
Shamran	58.19	7.50	40.50	18.75	99.00	115.00	120.00
SEm±	0.53	0.43	2.02	0.57	0.65	0.68	1.04
CD (P=0.05)	1.65	1.33	6.29	1.77	2.01	2.11	3.24

Table 5. Changes in TSS (°Brix) of fruits in Date palm cultivars during fruit growth

Treatments	April	May		June		July	Harvest
	30	15	30	15	30	15	
Halawy	13.85	15.26	16.68	19.72	30.41	39.00	41.28
Khalas	11.45	13.84	14.06	17.33	24.06	36.04	39.17
Khadrawy	11.23	12.51	13.67	15.90	23.43	33.75	37.39
Shamran	12.45	13.17	13.75	16.09	19.86	34.03	39.13
SEm±	0.49	0.34	0.29	0.38	0.72	0.58	0.48
CD (P=0.05)	1.51	1.05	0.91	1.18	2.23	1.81	1.49

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Improving post harvest quality of custard apple using modified atmospheric packaging and storage temperature

P. Baraily, R.A. Kaushik*, R.S.Rathore and D.K.Sarolia

Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur – 313001

*Corresponding author's E-mail: kaushik_ra@yahoo.co.in

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Abstract

Investigation on 'Effect of modified atmospheric packaging and storage temperature on shelf life of custard apple cv. Balanagar' was carried out with 14 treatment combinations. The uniform sized fully matured fruits of custard apple cv. Balanagar at colour turning stage were packed in medium density polyethylene bags (50 μ density) with mixture of different gaseous composition and stored in different storage temperatures. Two concentration of O₂ (5% and 10%), three concentration of CO₂ (10%, 15% and 20%) and one control (environmental gaseous composition with 21% O₂ and 0.03% CO₂) were used in packages. Fruits were stored at ambient and 12°C temperatures. Higher TSS and total sugar, retention of ascorbic acid, acidity, phenols and highest scores for overall organoleptic attributes were found in low concentration of O₂ and CO₂ in MAP and low temperatures storage. Finally this study indicated that custard apple fruit could be stored at 12°C for 10 days with MAP (5% O₂ and 10% CO₂) allowed conservation of fruits with highest quality parameters. It also indicate that stored custard apple fruit can be marketed for extended period and used for making various products.

Key word: Modified atmosphere packaging, storage temperature, shelf life

Introduction

Custard apple (*Annona squamosa* L.) popularly known as sitaphal, sugar apple, sweetsop, sharifa, and noina, is one of the most important underutilized finest fruit gifted to India by Tropical America and belongs to the family Annonaceae. In India area under custard apple is reported to be 53,000 ha. Custard apple is mainly grown in the states of Andhra Pradesh, Maharashtra, Madhya Pradesh, Uttar Pradesh and Rajasthan. Custard apple has wide adaptability to soil and climatic conditions, tolerant to drought and salinity and resistance against pests and diseases due to its hardy nature and escape from animal damage. Among the *Annona* fruits, sugar apple pulp is considered as sweetest with a good flavour and low acidity (FAO,8). The 100g pulp contains 70.5 g moisture, 23.5 g carbohydrate, 1.6 g protein, 0.9 g minerals, 1.5 mg iron, 17 mg calcium, 47 mg phosphorus, 105 I.U. calorific value and 37 mg vit. C (Dashora *et al.*, 6). *Annonas* are climacteric fruits (Biale and Barcus, 5). Custard apple fruits are perishable, ripening of *Annona* fruits are characterized by high respiration and high ethylene production rates which makes it highly perishable (Pareek *et al.*, 11), so under ordinary conditions, fruits can be kept well only for 3-4 days after harvest. Rapid softening of fruits during transportation

and at retail stores is the biggest ongoing problem. The use of several techniques including the use of modified atmosphere packing (MAP) and cold storage has proved to be useful in maintaining the quality of custard apple and increasing its shelf life. MAP is the replacement of air in a pack with a single gas or mixture of gases and proportion of each component is fixed when the mixture is introduced. The basic principle of MAP is to match the respiration of the product with the O₂ and CO₂ concentration and permeability of packages in order to modify the O₂ and CO₂ concentrations of the atmosphere to desired levels within the package (Beaudry and Lakakul, 4). Therefore, keeping the above factors in view the present study "Effect of modified atmospheric packaging and storage temperature on shelf life of custard apple cv. Balanagar" was conducted in Post Harvest Technology Laboratory, Department of Horticulture, Rajasthan College of Agriculture, Udaipur during 2013-14.

Materials and methods

The uniform sized fully matured fruits of custard apple cv. Balanagar were obtained from Instructional Farm of KVK, Chittorgarh under Maharana Pratap University of Agriculture and Technology, Udaipur and brought to the

Post Harvest Technology Laboratory of the Department of horticulture on the same day. Custard apple fruits were inspected thoroughly for any damage and spoilage. The uniform sized fully matured fruits of custard apple cv. Balanagar at colour turning stage were packed in medium density polyethylene bags (50 μ density) with mixture of different gaseous composition and stored in ambient and 12°C temperatures. The modified atmospheres were created by using a gas mixture. The experiment was consisting of 14 treatment combination comprising: G₁T₁= control (21% O₂ & 0.03% CO₂) + ambient storage temperature; G₁T₂= control (21% O₂ & 0.03% CO₂) + 12°C storage temperature; G₂T₁= 5% O₂ & 10% CO₂ + ambient storage temperature; G₂T₂= 5% O₂ & 10% CO₂ + 12°C storage temperature; G₃T₁= 5% O₂ & 15% CO₂ + ambient storage temperature; G₃T₂= 5% O₂ & 15% CO₂ + 12°C storage temperature; G₄T₁= 5% O₂ & 20% CO₂ + ambient storage temperature; G₄T₂= 5% O₂ & 20% CO₂ + 12°C storage temperature; G₅T₁= 10% O₂ & 10% CO₂ + ambient storage temperature; G₅T₂= 10% O₂ & 10% CO₂ + 12°C storage temperature; G₆T₁= 10% O₂ & 15% CO₂ + ambient storage temperature; G₆T₂= 10% O₂ & 15% CO₂ + 12°C storage temperature; G₇T₁= 10% O₂ & 20% CO₂ + ambient storage temperature; G₇T₂= 10% O₂ & 20% CO₂ + 12°C storage temperature, and sampled periodically for analysis of various, biochemical and sensory parameters after every 48 hours. The whole experiment was conducted using a factorial completely randomized design with three replications.

Observation were recorded on biochemical attributes including TSS (°B), acidity (%), ascorbic acid (mg 100g⁻¹), pH, reducing sugar (%), total sugar (%) and phenols (%); and overall organoleptic scores. TSS of the Pulp was determined by using "Zeiss" Hand Refractometer, pH of fruit pulp was directly determined by sensor based digital pH mete, reducing sugars content was measured by using dinitrosalicylic acid, total phenol content of the fruit was determined by Folin- ciocalteau reagent. All other quality parameters of fruits were analyzed as per standards methods given in (A.O.A.C., 1).

Results and discussion

The TSS contents of sugar apple fruits increased during storage at different temperatures (Bolivar-Fernandez *et al.*, 2005; Prasanna *et al.*, 13). Present study showed that the TSS (°B) of custard apple fruits increased with the advancement of storage period up to climacteric rise and thereafter decreased and the maximum TSS at the termination of the experiment was found in G₂ gaseous composition and T₂ storage temperature, also depicted in Fig. 1, might be due to starch gets hydrolyzed into mono and disaccharides which in turn may lead to an increase in total soluble solids and similar results were also reported by Yang *et al.*, 14; Mohsen, 8. It is evident from the data presented in Fig. 2, on 8th day of storage, the lowest total

sugar was observed in G₅T₂ (18.66%) and highest in G₁T₁ (20.90%). Further, on 10th day of storage, the minimum total sugar was observed in G₃T₂ (12.00%) and maximum in G₂T₂ (14.46%) treatment combinations. A general decrease in sucrose content in bayberry fruit stored at different temperatures was observed, while there was a marked increase in fructose and glucose contents during the initial period of storage, and then their values declined (Yang *et al.*, 14). The increase in fructose and glucose contents could be due to hydrolysis of sucrose, yielding glucose and fructose (Ding *et al.*, 7; Patel *et al.*, 12). It is clear from the data presented in Table 1, that at the end of the experiment, maximum ascorbic acid was observed in G₂T₂ (27.06 mg 100⁻¹) while minimum in G₁T₁ (23.69 mg 100⁻¹) and G₂T₂ was found at par with G₃T₂ and G₇T₂. The ascorbic acid content of fruits decreased with the advancement of storage period. The decrease in ascorbic acid during storage is probably due to the process of oxidation of ascorbic acid forming dehydro ascorbic acid by enzyme ascorbinase. The pH of custard apple fruits increased during storage and their values were significantly lowered by lower storage temperature. The values of pH stored at ambient and 12°C were around 4.75 and 4.61 respectively as presented in the Table 1, that the pH of bayberry fruit juice increased during storage, corresponding to a decreased in acidity at all storage temperatures (Yang *et al.*, 2010). The phenol content of custard apple fruits decreased with the advancement of storage time during the entire period of experiment and the rate of decrease was significantly affected by different gaseous composition during storage as presented in Fig 3. The total phenol content declined with advancement of storage and this loss of astringency is probably connected with increased polymerization of tannins. The results are in agreement with the findings of Mahajan (9) in apples.

On 8th day of storage, minimum overall organoleptic score was recorded in G₁T₁ and G₁T₂ (6.33) treatment combinations and maximum in G₂T₂ (8.33). But on 10th day of storage, all the treatment combinations were found non-significantly different with each other. Minimum score of overall acceptability of sapota fruit was observed in 40 μ LDPE bags that could be attributed to insufficient O₂ within package (anaerobic respiration) due to low permeability of 40 μ LDPE film was reported by Antala *et al.*, (2). These results support the present investigation in custard apple fruit.

Based on the above findings, it could be recommended that custard apple can be stored at 12°C for 10 days with MAP (5% O₂ & 10% CO₂) with highest quality parameters. This standardized storage technology has promising future for technology utilization by small, medium and large scale processor and entrepreneurs. The stored fruit can be marketed for extended period and used for making various products.

Table 1. Interaction effect of gas composition in package and storage temperature on ascorbic acid (mg/100g) and pH during storage

Treatment combinations	Ascorbic acid (mg/100g)					pH				
Storage day	2	4	6	8	10	2	4	6	8	10
G ₁ T ₁	47.08	40.32	31.16	26.02	23.69	4.00	4.71	5.03	5.35	5.67
G ₁ T ₂	47.32	39.56	31.86	27.04	25.17	3.64	4.14	4.64	5.14	5.65
G ₂ T ₁	47.32	40.56	33.35	27.14	25.10	2.43	2.73	3.13	3.63	4.23
G ₂ T ₂	52.08	48.32	37.16	30.12	27.06	1.90	2.40	2.90	3.40	3.90
G ₃ T ₁	48.08	40.32	32.56	28.06	24.02	3.65	4.15	4.65	5.15	5.65
G ₃ T ₂	52.84	47.48	40.32	32.38	26.98	3.37	3.87	4.37	4.87	5.37
G ₄ T ₁	47.08	40.32	33.32	27.80	24.03	3.63	4.13	4.63	5.13	5.67
G ₄ T ₂	53.94	47.18	36.56	28.06	25.06	3.31	3.81	4.31	4.81	5.31
G ₅ T ₁	52.08	40.32	33.32	27.18	24.01	2.90	3.40	3.90	4.40	4.90
G ₅ T ₂	55.14	48.28	37.46	29.16	24.10	3.14	3.64	4.14	4.64	5.14
G ₆ T ₁	53.28	47.32	35.16	28.03	24.48	3.30	3.80	4.30	4.80	5.30
G ₆ T ₂	52.84	49.08	37.32	29.80	24.70	3.16	3.66	4.16	4.66	5.61
G ₇ T ₁	52.08	46.12	37.96	28.26	25.20	3.29	3.79	4.29	4.79	5.29
G ₇ T ₂	52.08	46.02	38.51	29.16	26.14	2.80	3.70	4.22	4.75	4.69
SEm±	0.78	0.68	0.54	0.44	0.40	0.02	0.03	0.03	0.03	0.06
CD (P=0.05)	2.26	1.94	1.55	1.28	1.15	0.07	0.09	0.09	0.09	0.17

*Significance at 5 % level of significance.

G₁T₁=control (21% O₂&0.03% CO₂)+ambient storage temperature; G₁T₂=control (21% O₂&0.03% CO₂)+12°C storage temperature; G₂T₁=5% O₂&10% CO₂+ambient storage temperature; G₂T₂=5% O₂&10% CO₂+12°C storage temperature; G₃T₁= 5% O₂&15% CO₂+ambient storage temperature; G₃T₂= 5% O₂&15% CO₂+12°C storage temperature; G₄T₁=5% O₂&20% CO₂+ambient storage temperature; G₄T₂=5% O₂&20% CO₂+12°C storage temperature; G₅T₁=10% O₂&10% CO₂+ambient storage temperature; G₅T₂= 10% O₂ & 10% CO₂+12°C storage temperature; G₆T₁= 10% O₂&15% CO₂+ambient storage temperature; G₆T₂= 10% O₂&15% CO₂+12°C storage temperature; G₇T₁=10% O₂&20% CO₂+ambient storage temperature; G₇T₂= 10% O₂ & 20% CO₂+12°C storage temperature.

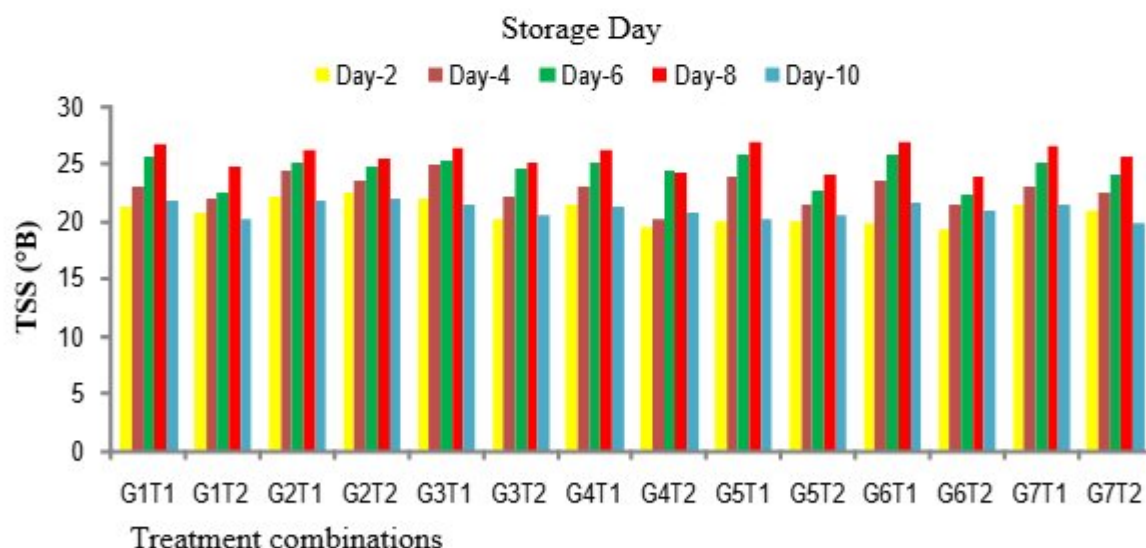


Fig 1. Interaction effect of gas composition in package and storage temperature on TSS (°B) during storage

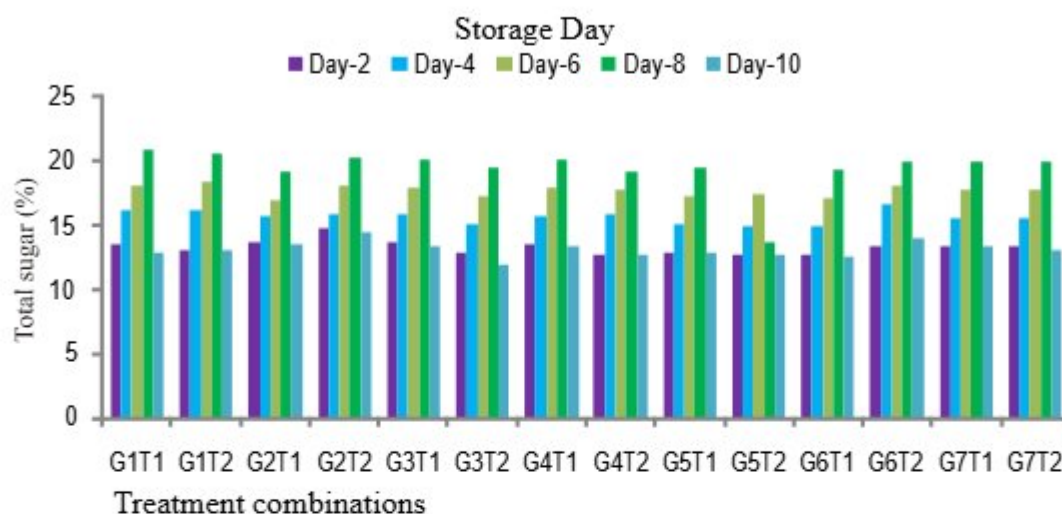


Fig 2. Interaction effect of gas composition in package and storage temperature on total sugar (%) during storage

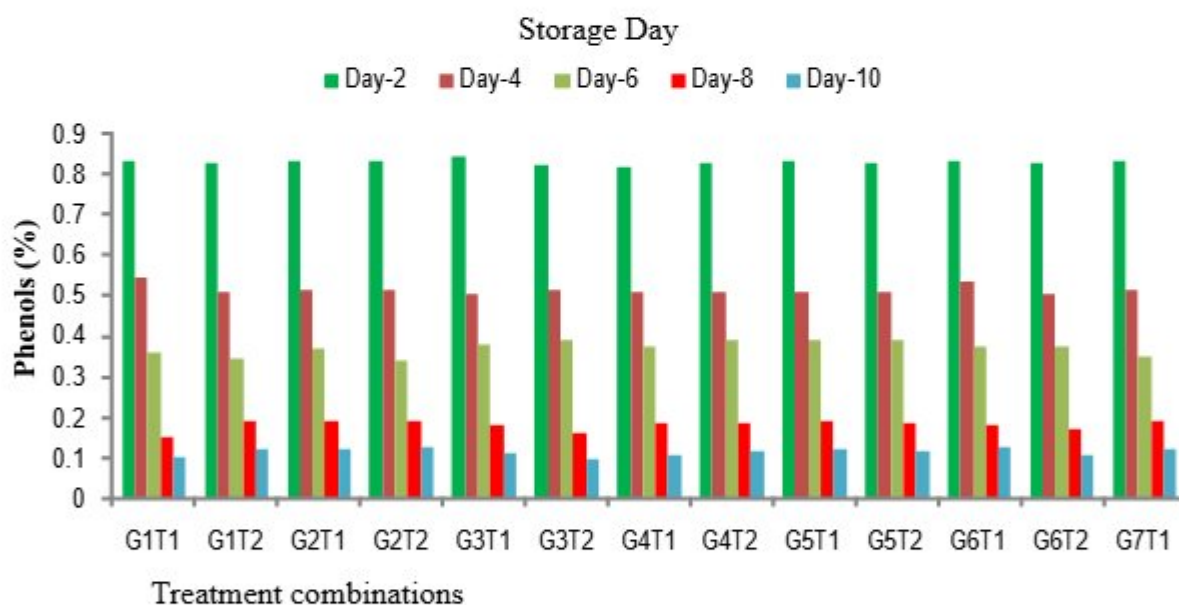


Fig 3. Interaction effect of gas composition in package and storage temperature on phenols (%) during storage

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Comparative effect of organic manures and inorganic fertilizers on vegetative growth, yield and quality of Ber (*Zizyphus mauritiana* Lamk.) cv. Gola under Semi-arid conditions

Rajbala Choudhary , O. P. Garhwal, M R Choudhary , Hari Dayal Choudhary and Manoj Kumar Rolanis
Department of Horticulture, S.K.N. College of Agriculture
S.K.N. Agriculture University, Jobner, Jaipur
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Abstract

An experiment was carried out at S.K.N.A.U., Jobner (Jaipur) Rajasthan to find out the comparative effect of organic manures and inorganic fertilizers on growth parameters of three years old ber orchard cv. Gola. Four levels of organic manures (control, FYM @ 20 kg/plant, Vermi- compost @ 6 kg/plant and poultry manure @ 8 kg/plant) and five levels of RDF (control, 50% RDF, 75% RDF, 100% RDF and 125% RDF) in Randomized Block Design with three replications were taken to provide balance fertilization of ber under semi-arid region of northern India during 2015-16. The experimental results revealed that application of Vermi-compost @ 6 kg/plant and 125% recommended dose of fertilizers significantly influence the growth parameters (Plant height, plant spread (E-W and N-S), number of primary branches, average length of primary branch, number of secondary branches per primary branch and leaf area), fruit yield (kg/plant and q/ha) and fruit quality (TSS and acidity content) of experimental plants

Key words: Organic manures, inorganic fertilizers, semi-arid conditions, vegetative growth, fruit yield and quality.

Introduction

Indian jujube (*Zizyphus mauritiana* Lamk.) is an important fruit crop of hot arid ecosystem due to less water requirement, wider adaptability, hardy nature and its ability to flourish well even in poor quality soil. So it is known as "King of Arid Fruits". It belongs to the family Rhamnaceae which has about 50 genera and more than 600 species (Pareek, 1983). In India, ber is being cultivated on an area of about 4845 hectares with production of 66,296 metric tonnes (Anonymous, 2014). Madhya Pradesh, Bihar, Punjab, Haryana, Gujarat and Rajasthan are the major ber growing states. Among the different cultivars of ber, Gola is an extremely drought hardy, early & extensively grown variety. The fruits are round in shape & skin is golden yellow when ripe. The TSS content of pulp is 16.0-20.0 per cent, vitamin 'C' content ranges from 70-130 mg/100g, acidity varies from 0.14-0.25 per cent and average yield is about 80 kg per tree.

The Indian jujube is grown chiefly for its fruits which may be eaten fresh, dried or canned, smoked and pickled or used in drinks. Several products like ber butter, ber squash or juice, ber murabba, ber pulp, ber jam and dehydrated or dried products may also be made of ber fruits (Pareek, 1983 and Yamdgni, 1985). Various Ayurvedic and

Yunani medicines contain ber extract which is said to be blood purifier and also help in digestion. Ber tree is important host plant for insect *Laccifer lacca* (Kerr.) which secretes a resinous substance on the twigs which is the raw materials for shellac preparation.

It has a remarkable adaptability enabling it to grow in a wide range of agro-climatic situations and soils (Rana *et al.*, 1979). It is well documented that growth and yield of trees are greatly influenced by a wide range of nutrients. The cultivation of this crop in arid and semi-arid regions is mainly done but, due to one or another reason farmers are not harnessing the desired production potential of the crop. The potent reasons for lesser productivity could be attributed to poor management. Ber produces fruits continuously for a long time, thus it needs proper and integrated nutrients to have regular feeding at vegetative as well as reproductive phase of the tree. The intensively cultivated soils do have the problems of fast depletion of plant nutrients and become deficient not only in macro but also in micro nutrients (Singh *et al.*, 1998). An approach involving chemical fertilizers and organic manures to bridge this gap between nutrient demand and supply for giving a boost to crop production is only the solution. The situation further aggravates for the light soil of Rajasthan, where

nutrient use remains much lesser than the removal (Gupta, 2001).

Keeping the above facts into consideration, an investigation on organic and inorganic sources of nutrients in Ber (*Zizyphus mauritiana* Lamk.) was carried out to identify the comparative effect of different sources of nutrients with respect to vegetative growth, fruit yield and quality of ber plants.

Materials and Methods

An experiment was conducted at Horticulture farm, S.K.N. college of Agriculture, Jobner (Jaipur) during July, 2015 to February, 2016 in the orchard of Ber cv. Gola under loamy sand soils. The plants of uniform size, vigorous and three years age after budding spaced at 6 m x 6 m were selected. It consisted of 20 treatment combinations with four levels of organic manures (M_0 -control, M_1 -FYM @ 20 kg/plant, M_2 -vermicompost @ 6 kg/plant and M_3 -poultry manure @ 8 kg/plant) and five levels of RDF (F_0 -control, F_1 -50% RDF, F_2 -75% RDF, F_3 -100% RDF and F_4 -125% RDF) in Randomized Block Design with three replications.

The full dose of organic manures was applied as soil application in July, 2015. The recommended doses of fertilizers 1100 g urea, 1400 g SSP and 200 g MoP per tree were applied. Full dose of SSP, MoP and half dose of urea in various treatments were applied as basal dose in July, 2015. Remaining half dose of urea was applied before flowering. The fertilizers were applied to the top soil around the plant. The fertilizers uniformly mixed into the soil and then levelled. Irrigation was applied immediately after application of manures and fertilizers. The role of nutrient elements either alone or in combination with other sources (organic manures/fertilizers) has been well established in many fruit crops; while such studies are very meagrely available in ber (Katiyar *et al.*, 2012).

Growth attributes in terms of plant height (cm), trunk girth (cm), plant spread (E-W and N-S in cm), average length of primary branch (cm) and number of secondary branches per primary branch of experimental plants were recorded twice in a year, before application of treatments in the month of July, 2015 and at full bloom stage in the month of October, 2015 and gain in these parameters were calculated with the help of thread and meter scale. The number of primary branches per plant and average leaf area using Leaf Area Meter, LICOR-3000 Lincoln, USA and expressed as cm^2 was measured at full bloom stage in the month of October, 2015.

Ripened fruits were harvested and the weight was recorded by summing up the total of fruits at different pickings obtained during January 8, 2016 to February 25, 2016 from each experimental plant. Quality components viz., total soluble solids ($^{\circ}$ Brix) with the help of ZeissTM hand refractometer and acidity content (A.O.A.C., 1980) of ripe fruits were also analyzed.

Statistical analysis

To test the significance of variation in the data obtained from various growth, yield and quality characters, the technique of statistical analysis of variance was suggested by Fisher (1950) for Randomized Block Design. Significance of difference in the treatment effect was tested through 'F' tests at 5 per cent level of significance and CD (critical difference) was calculated, wherever the results were significant.

Results and Discussion

Vegetative growth

Perusal of data regarding to plant height, plant spread (E-W and N-S), number of primary branches, average length of primary branch, number of secondary branches per primary branch and average leaf area of experimental plant presented in table-1 significantly affected by application of various organic manures and fertility levels.

The maximum gain in plant height (77.15 cm), gain in plant spread in E-W direction (111.85 cm) and N-S direction (109.58 cm), number of primary branches (22.00), gain in average length of primary branch (91.25 cm), number of secondary branches (8.51) and average leaf area ($29.12 cm^2$) were observed in treatment M_2 (Vermi-compost @ 6 kg/plant) which is significantly superior than rest of the treatments except M_3 (Poultry manure @ 8 kg/plant). The data presented in table 1 indicates that application of different organic manures and fertility levels brought about non-perceptible variation to gain in trunk girth. All the above vegetative growth parameters of experimental plants were recorded significantly poor under control.

As Vermicompost is a slow releasing organic manure which contains most of the macro as well as micro nutrients in chelated form and fulfill the nutrient requirement of plant for longer period. Vermicompost helps in reducing C:N ratio, increased humic acid content, cation exchange capacity and water soluble carbohydrates (Talashilkar *et al.*, 1999). The improvement in plant height by the application of organic manures like vermin-compost might be due to better moisture retention capacity, supply of micronutrients and easy availability of major nutrients of soil (Reddy *et al.* 1998). Improvement in soil parameters might have helped in increasing the absorption of nutrients from soil, enhanced carbohydrate assimilation and production of new tissues, which ultimately increased vegetative growth.

A further reference to data showed in table-1 indicated that application of 125% RDF recorded maximum gain in plant height (78.75 cm), gain in plant spread in E-W direction (118.51 cm) and N-S direction (115.17 cm), number of primary branches (22.15), gain in

average length of primary branch (97.28 cm), number of secondary branches (8.62) and average leaf area (28.83cm²) which was significantly higher as compared to control, 50% RDF and 75% RDF but found statistically at par with treatment F₃ (100% RDF). The better growth and development of plant under this treatment might be due to better nutritional environment in root zone as well as in plant system.

Nitrogen, phosphorus and potash are most indispensable among all mineral nutrients for growth and development of plant as it is basis of fundamental

constituents of all living matter present. The biological role of NPK as an essential constituent of chlorophyll and nucleic acid, in harvesting solar energy, energy transformation from phosphorylated compound, transfer of genetic information, regulation of cellular metabolism and structural unit compound is well known. All these are found abundantly in the growing and storage organ, promote healthy root, shoot and full development (Devlin and Witham, 1986). The findings are in agreement with the reports of Lal and Dhaka (2003), Prasad (2005) and Devashi (2012).

Table 1. Effect of organic manures and fertility levels on vegetative growth parameters of Ber cv. Gola

Treatments	Plant height (cm)	Trunk girth (cm)	Plant spread in E-W direction (cm)	Plant Spread in N-S direction (cm)	Number of primary branches (cm)	Average length of primary branch (cm)	Number of secondary branches (cm)	Average leaf area (cm ²)
Organic Manures								
M ₀	66.12	2.55	88.64	86.92	18.55	69.20	4.65	23.23
M ₁	72.04	2.65	101.54	98.20	20.01	80.40	6.71	26.12
M ₂	77.15	2.76	111.85	109.58	22.00	91.25	8.51	29.12
M ₃	75.30	2.71	110.36	107.31	21.22	89.28	8.35	28.11
SEm±	1.29	0.07	2.25	2.92	0.36	2.02	0.14	0.58
CD (P=0.05)	3.69	NS	6.43	8.37	1.02	5.78	0.40	1.66
Fertility Levels								
F ₀	63.14	2.52	77.95	75.09	17.84	56.69	4.33	23.42
F ₁	69.79	2.62	94.66	92.35	19.43	75.71	6.20	25.56
F ₂	74.36	2.70	108.48	105.22	20.81	87.63	7.60	26.76
F ₃	77.22	2.74	115.89	114.68	21.99	95.36	8.52	28.65
F ₄	78.75	2.75	118.51	115.17	22.15	97.28	8.62	28.83
SEm±	1.44	0.08	2.51	3.27	0.40	2.26	0.15	0.65
CD (P=0.05)	4.16	NS	7.25	9.44	1.15	6.52	0.45	1.87

Fruit yield

The data pertaining to the effect of organic manures and fertility levels (NPK) viz., fruit yield (kg/plant) and fruit yield (q/ha) of ber are summarized in table-2. Yield is a complex character which depends on yield contributing characters. Application of organic manures significantly affected the fruit yield per plant as well as per hectare. The maximum Fruit yield (15.31 kg/plant and 42.56 q/ha) under treatment M₂ (Vermi-compost @ 6 kg/plant) was observed which was significantly higher as compared to control and M₁ (FYM @ 20 kg/plant. But it was statistically at par with treatment M₃ (Poultry manure @ 8 kg/plant).

The significant improvement in fruit yield on account of vermin-compost application was largely a function of improved growth i.e. multiplication & cell elongation, tissue differentiation and therefore consequent increase in yield attributes and yield (Singh and Meena, 2004). The increase in yield with application of vermin-compost may also be ascribed to sustained availability of balanced nutrient throughout the growing period and which

resulted increased vegetative growth. The narrow C:N ratio might also helped in increased nutrient uptake and synthesis of carbohydrates which ultimately enhanced yield.

Similarly, application of various fertility levels (NPK) had also significantly influenced the fruit yield. The maximum fruit yield (15.11 kg/plant and 42.02q/ha) was found under treatment F₄ (125% RDF) which was statistically at par with F₃ (100% RDF). The application of inorganic fertilizers might have also increased the availability of nutrients directly which in turned increased fruit yield. The findings of present investigation are in agreement with those of Prasad (2005), Dalal *et al.* (2011), Dayal *et al.* (2011), Dhomane and Kadam (2013).

Fruit quality

The data regarding to total soluble solids and acidity contents in fruits mentioned in table-2 revealed that application of different organic manures and fertility levels (NPK) gave significant results. The maximum total soluble solids (19.55°Brix) and minimum acidity (0.397%) were

observed in treatment M₂ (Vermi-compost @ 6 kg/plant) which was significantly higher to rest of the treatments except M₃ (Poultry manure @ 8 kg/plant). The increase in TSS content and decrease in acidity content in fruits might be clear to better availability of desired and required quantity of nutrients for longer period in root zones of plant resulting from its solubilization of organic matter and chelation of available nutrients.

The TSS and acidity content in fruits also affected significantly by application of various fertility levels (NPK). The application of treatment F₄ (125% RDF) recorded

maximum TSS (20.19⁰Brix) and minimum acidity (0.367%) in fruits which was found statistically at par with F₃ (100% RDF) but significantly higher to other treatments. Arora *et al.* (2012) reported that potassium is a major nutrient element essential for translocation of sugar and increase TSS content in fruits. The increase in TSS content and decrease in acidity content in ber fruits may also be due to increased activity of nitrate reductase enzyme and enhanced synthesis of certain amino acid and proteins. Similar results were also obtained by Bhatia *et al.* (2001), Mahalle *et al.* (2001) and Kundu *et al.* (2011).

Table 2. Effect of organic manures and fertility levels on fruit yield and quality of ber cv. Gola

Treatments	Fruit yield (kg/plant)	Fruit yield (q/ha)	TSS (⁰ Brix)	Acidity (%)
Organic Manures				
M ₀	8.03	22.32	17.35	0.448
M ₁	12.00	33.36	18.38	0.421
M ₂	15.31	42.56	19.55	0.397
M ₃	14.59	40.56	19.31	0.414
SEm±	0.26	0.70	0.29	0.007
CD (P=0.05)	0.73	2.01	0.82	0.020
Fertility Levels				
F ₀	7.61	21.16	16.33	0.483
F ₁	11.01	30.60	17.87	0.449
F ₂	13.82	38.41	18.96	0.418
F ₃	14.86	41.31	19.90	0.383
F ₄	15.11	42.02	20.19	0.367
SEm±	0.29	0.78	0.32	0.008
CD (P=0.05)	0.83	2.26	0.93	0.023

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Frontline Demonstrations: An approach for management of chilli thrips (*Scirtothrips dorsalis* Hood)

Shakti Khajuria , A.K.Rai , Kanak Lata , Raj Kumar and J.K. Jadav
(ICAR-CIAH), Krishi Vigyan Kendra-Panchmahal, Vejalpur, Godhra, Gujarat 389 340

*Corresponding Author email : shaktikhajuria@gmail.com

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Abstract

Front line demonstrations were conducted to popularize the recommended practice for the management of chilli thrips in Panchmahals district of central Gujarat. Results indicated that application of insecticide in recommended practices, i.e., ethion 40 % + cypermethrin 5 % @ 0.045 % was found most effective in managing chilli thrips (1.07/leaf) as compared to farmers practices (3.09/leaf). The yield of chilli in recommended practice was 128.13 q/ha as compared to farmer's practices (80.30 q/ha). The percentage increased in the yield over farmer's practices was computed to be 59.56. Results of study on economic analysis of the yield performance revealed that the recommended practices recorded appreciable higher gross returns (10,2500/ha) and net return (61,725/ha) with higher benefit cost ratio (2.51) as compared to farmer's practices (1.62). The technology gap (21.87 q/ha), extension gap (47.83 q/ha) and the technology index values (14.58 %) were recorded. Frontline demonstrations brought out that the recommended practice was feasible and economically viable over farmers practice and was a better option to adopt for managing chilli thrips.

Key words: Frontline demonstrations, insecticide, *Scirtothrips dorsalis*, chilli

Introduction

Chilli (*Capsicum annum* L.) is one of the important vegetable and condiments crop having immense commercial dietary and therapeutic values and grown throughout the year. The total area, production and productivity of chilli in India is 7.94 lakh ha, 13.04 lakh MT and 1.64 MT/ha, respectively (Anonymous, 2012). In Gujarat, area and production of chilli was 43.40 (000 ha) and 68.53 MT respectively (Anonymous, 2012). In Panchmahals district of Gujarat, chilli is one of the most important vegetable crops. The area and production of chilli of the district were 700 ha and 2170 MT, respectively (Anonymous, 2010). In Gujarat, the productivity of chilli is low as compared to other states and average productivity of the country. A number of limiting factors attributes for its low productivity. Of the various biotic stresses, ravages caused by insect pests are significant ones. Nearly, 25 insects have been recorded attacking chilli in India. Among them, thrips, *Scirtothrips dorsalis* Hood (Thripidae: Thysanoptera) is considered as the most serious and important pest. The incidence of thrips starts from nursery and continues till harvest of the produce. Both nymphs and adults of thrips cause damage by scraping the epidermis of the leaves and suck the cell sap from the leaves resulting in upward rolling of the margin of the leaves followed by reduction in leaf size. The damage results from sucking of the cell sap leading to crinkling and

curling of leaves and loss of plant vigour. Thrips infestation is a persistent problem for chillies. Severe infestation leads to 30-50 per cent yield loss (Jayaraj and Muthukrishnan, 2013).

Borah (1987) estimated losses due to thrips in chilli ranged from 50 to 90 per cent at Dharwad. Patel and Gupta (1998) also expected the yield loss of green chilli due to thrips ranged from 60.5 to 74.3 per cent.

Besides damage, this thrips act as vector in transmission of leaf curl disease. Use of chemical insecticides is one of the most common and popular method of its control. Present study was undertaken to demonstrate the efficacy of ethion 40 % + cypermethrin 5 % EC, a pyrethroid and organo phosphate combination insecticide for the control of chilli thrips under farm conditions. In view of the above factors, frontline demonstrations were undertaken in a systematic manner on farmers' field to show the efficacy of recommended technology and convince the farmers to adopt the same.

Materials and Methods

The field experiments were carried out during Kharif season of 2011-12 to demonstrate the efficacy of ethion 40 % + cypermethrin 5 % @ 0.045 % in the control of the chilli thrips under FLD activity of Krishi Vigyan Kendra-Panchmahal (Gujarat) at farmer's field. Twelve

innovative and receptive farmers from taluka Kalol were selected for conducting the demonstrations to ensure their active participation. Ethion 40 % + cypermethrin 5 % @ 0.045 % was used as a recommended pesticide to control the chilli thrips while the prevailing farmers practice i.e. dusting of methyl-parathion 2% dust along with ash was treated as control for comparison.

Experimental trial was conducted by following all standard and recommended packages of practices such as tillage, spacing, irrigation and disease control for cultivation of the crop. Foliar application of recommended insecticide was given as per schedule using a manually operated knapsack sprayer. Initial application was made at an economic threshold level i.e. 1thrip/ leaf, whereas, subsequent two sprays were done at an interval of 15 days. The population of thrips was recorded after each spray from 3 leaves (upper, middle and bottom) of ten randomly selected plants per plot.

Production and economic data of recommended practices for front line demonstrations and farmers' practices were collected. In the present study, technology gap, extension gap and technology index were calculated using the formula given by Samui *et al.* (2000):

Technology gap = Potential yield - Demonstration yield;

Extension gap= Demonstration yield -Yield under existing practice;

Technology index = Potential yield - Demonstration yield/Potential yield $\times 100$.

Statistical analysis

The data collected were transformed into square root values as per the standard requisites. The experiments were subjected to statistical scrutiny following the method of Panse and Sukhatme (1989) and the means were compared with Least Significant Difference (L.S.D.)

Result and Discussion

Performance of FLDs

A comparison of frontline demonstrations due to recommended technology and farmers practice were analyzed and presented in Table 1. In the present investigation, infestation of thrips started from 1st week after transplanting and remained in field till crop maturity (3rd week of February). Recommended practice, use of ethion 40

% + cypermethrin 5 % @ 0.045 %, recorded significantly lower mean thrips population as compared to farmers' practice. Thrips population varied from 1.07 (recommended practices) to 3.09 (farmers practices) thrips per leaf. In the present study, recommended practice was found to be effective in bringing down the chilli thrips population. These findings were in close agreement with Patel *et al.* (2009) who reported that per cent mortality of *S. dorsalis* by spray of ethion + cypermethrin was found significantly superior to rest of the insecticidal treatments followed by methomyl, diafenthiuron, lufeneuron, imidacloprid and triazophos. The yield performance of recommended practice was 128.13 q/ha which is almost 59.56 % higher than farmers practice (80.30 q/ha). Yield enhancement in chilli crops in evaluation of insecticides has been documented by Patel *et al.* (2009) who obtained significantly highest yield from ethion + cypermethrin sprayed plots and gave satisfactory control of chilli thrips.

From these results, it was evident that the recommended practice was better than the farmers practices under local conditions. Farmers were motivated by results of technologies applied in the front line demonstrations trials and it was expected that they would adopt this technology in the coming years. Yield of the front line demonstration trials and potential yield of the crop was compared to estimate the yield gaps which were further categorized into technology index.

The technology gap 21.87 q/ha show gap in the demonstration yield over potential yield. The frontline demonstrations was laid down under the keen supervision of KVK specialist at the farmer's field. The observed technological gap might be attributed to dissimilarities in soil fertility, salinity, erratic rainfall and vagaries of weather conditions in the region. Hence, to narrow down the gap between the yields of different varieties, location specific recommendation appeared to be essential. These findings were similar to the findings of Sharma and Sharma (2004).

Technology index show the feasibility of recommended practices at the farmer's field. The lower the value of technology index more is the feasibility. Result of study depicted in Table 1 revealed that the technology index value was 14.58 %. The results of the present study were in consonance with the findings of Hiremath and Nagaraju (2009) in case of onion crop.

Table 1. Yield attributes, technology gap and technology index of demonstration

Variables	Chilli thrips/leaf	Yield (q/h)	Yield increase (%) (q/h)	Technology gap (q/h)	Extension gap (q/h)	Technology index (%)
Farmer's practice	3.09 (2.01)	80.30				
Recommended practice*	1.07 (1.43)	128.13	59.56	21.87	47.83	14.58
S.E $\pm$	0.04	1.11				

CV	8.95	3.69			
LSD (P = 0.05)	0.14	3.50			

*Foliar spray of ethion 40 % + cypermethrin 5 % @ 0.045 %, Figures in parenthesis are transformed values of $\sqrt{x+1}$

The economics of chilli production under front line demonstrations were estimated as presented in Table 2. Economic analysis of the yield performance revealed that front line demonstrations recommended practices recorded higher gross returns (Rs. 102,500/ha) and net return (Rs. 61,725/ha) with higher benefit cost ratio (2.51) as compared to farmers practices. These results were in accordance with

the findings of Byrappa *et al.* (2012). Further, additional cost of Rs. 2,175 /ha in demonstration acquired on additional net return of ` 38,260/ha with an incremental benefit cost ratio 17.59 suggesting its higher profitability and economic viability of the demonstration. Similar results were also reported by Hiremath and Nagaraju (2009).

Table 2. Economics of frontline demonstrations

Variables	Cost of cultivation (Rs./h)	Gross return (Rs./h)	Net return (Rs./h)	Benefit cost ratio
Farmer's practice	38,600	64,240	25,640	1.62
Recommended practice	40,775	102,500	61,725	2.51
Additional in recommended practice	2,175	38,260	36,085	17.59*

*Incremental benefit cost ratio

Conclusion

Frontline demonstrations clearly brought out that the adoption of recommended practice (ethion 40 % + cypermethrin 5 % @ 0.045 %) was feasible, economically viable and effective technology for management of chilli thrips. The demonstration convinced most of the farmers to use recommended technology on account of its obvious advantages and effective management of chilli thrips. These innovative practices will help in solving the farmer's problem, decision-making and ability to modify their farming practices.

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Rooting response of pomegranate cv. Bhagwa cuttings to different media and growth regulators

M.K. Dhakar¹, D.K. Sarolia^{2*}, R.A. Kaushik³, M.L. Bana⁴

Rajasthan College of Agriculture, MPUAT, Udaipur 313001, India

¹ Scientist (Fruit Science), ICAR-RCER, Research Centre, Ranchi ² Senior Scientist, CIAH, Bikaner ³ Professor, Dept. of Horticulture, RCA, MPUAT, Udaipur, ⁴ Assistant Agriculture Officer, Rajasthan

*Corresponding author's email: deephorti@gmail.com

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Abstract

An experiment was conducted to study the influence of different media and growth regulators on the rooting and sprouting of hardwood cuttings of pomegranate cv. Bhagwa. Hardwood cuttings of diameter 0.8-1.0 cm having length 20-25 cm were taken and subjected to following treatments, viz., NAA-2500 ppm (T₁), NAA-5000 ppm (T₂), distilled water without growth regulator as control (T₃), Seradex rooting powder (T₄), IBA-2500 ppm (T₅) and IBA-5000 ppm (T₆) and then planted in vermiculite (M₁), cocopeat (M₂), sand (M₃) and soil (M₄) as rooting media. The results clearly demonstrate that cocopeat showed significantly higher bud sprout (5.54), shoot length (21.35 cm), root length (17.48 cm) and survival per cent (74.17) of hardwood cuttings. Among the different growth regulator maximum number of sprouts (4.88), shoot length (22.93 cm), root length (19.54 cm) and per cent survivability (73.0%) were registered with IBA 5000 ppm treatment. The interaction of cocopeat + IBA 5000 ppm was found to be most effective for encouraging the number of shoots (7.60), shoot length (26.70 cm), root length (25.60 cm), survivability of cuttings (85%) and root density.

Key Words: Auxin, hardwood cutting, pomegranate, potting media.

Introduction

The Punicaceae family has only two members, one of which is cultivated pomegranate (*Punica granatum* L.). Pomegranate is a high value fruit crop due to high return and export demand at the world level. It is a very suitable fruit, which can be grown in arid and semi-arid areas successfully. Air-layering and hardwood cuttings are employed for its commercial propagation. Though air-layering is successful in pomegranate but it is expensive, cumbersome and it adversely affects the growth of the mother trees (Purohit, 1981) and limited number of plants can be obtained. Hence, propagation by means of stem cuttings is convenient and a cheap method. Cutting is a commercial method of propagation in pomegranate and its propagation by means of hardwood cuttings is generally practiced but the rooting is hard (Singh *et al.*, 2011). A bound cardinal of attempts are made to improve the rooting in pomegranate through different potting media (Muhammed *et al.*, 2005; Alikhani *et al.*, 2011; Gurjar and Patel 2007; Saroj *et al.*, 2008; Hussain *et al.*, 2012) and growth regulators (Polat and Caliskan, 2009; Sandhu *et al.*, 1991; Ghosh *et al.*, 1998; Hore and Sen, 1993; Jain and Parmar, 1996; Navjot and Kahlon, 2002; Ram *et al.*, 2005; Tripathi, and Shukla, 2004; Singh *et al.*,

2011; Owis, 2010). In order to abate the high mortality of rooted cuttings in field, it is highly desirable to build a healthy and well developed root system in the hardwood cuttings. However, there is limited information on combined application of rooting media and growth regulators. Therefore, in this study different media and growth regulators were used to improve the rooting in Bhagwa cultivar.

Materials and Methods

The experiment was carried out to examine the effect of different media and growth regulators on the rooting and sprouting of pomegranate cuttings of cv. Bhagwa. This study was carried out in the Horticultural Farm, Rajasthan College of Agriculture, Udaipur during the year 2010-2011. Hardwood cuttings of diameter about 0.8-1.0 cm having length 20-25 cm were taken in the month of February. The cuttings were subjected to following treatments: NAA-2500 ppm (T₁), NAA-5000 ppm (T₂), distilled water without growth regulator as control (T₃), Seradex rooting powder (T₄), IBA-2500 ppm (T₅) and IBA-5000 ppm (T₆). The 1-2 cm basal part of the cuttings were dipped with plant growth regulators by quick dip method for 10 sec. and then planted in beds of vermiculite (M₁),

cocopeat (M₂), sand (M₃) and clay loam soil (M₄) rooting media in mist house. Cuttings were planted in 10 cm between rows and 5 cm within row spacing. There were three replications and each replicate had 100 cuttings. In this study, number of sprouts/cutting, shoot length from emerging point (cm), per cent survival of cutting (%), root length (cm) and root density parameters were determined. Number of sprouts/cutting was counted one month after planting (MAP). Shoot length, root length (measured with measuring tape) and per cent survival of cutting were measured three months after planting, whereas, root density was categorized as low (less than 20 roots / cutting), medium (less than 40 but more than 20 roots / cutting) and high (more than 40 roots / cutting) measured two months after planting. Statistical analysis was carried out using SAS software. The experiment was laid out in factorial completely randomized blocks design and the differences between the means were compared using least significant difference at 5%.

Results and Discussion

Results revealed that growing media, plant growth regulators and its interaction significantly influenced the number of sprouts from the cuttings and its length along with root length, per cent survival and root density (Table 1&2; Fig. 1).

Effect of growing media: It is clear from the data (Table 1) that the significantly higher sprout numbers (5.54), shoot length (21.35 cm), root length (17.48 cm) and survival (74.17%) of hardwood cuttings were recorded in cocopeat based growing media (M₂), while these attributes were minimum under soil media (M₄). However, M₁ and M₃ treatments found at par. Rooting performance of hardwood cuttings depends on the type of medium used in the propagating structure. This is so because the various materials and mixes of materials that can be used in rooting of cuttings provide physical support, oxygen, nutrients and water. Cocopeat is considered an ideal growing media component with acceptable pH, electrical conductivity (EC) and other chemical attributes. Cocopeat being inert with qualities like water retention and substrate aeration might have helped cuttings to establish. Soil alone showed a very poor rooting due to algae and fungal contamination coupled with water logging. Alikhani *et al.* (2011) observed highest roots length on sand + peat medium with three bud cuttings in pomegranate. Albouyeh (2007) for citrus cuttings recommends only peat or mixture of peat, perlite and

cocopeat with 2:2:1 ratio for plant height and the increase in leaf number. When *in vitro* rooted plantlets of *Garcinia indica* were transferred to different media for acclimatization then plants grown in cocopeat showed maximum survival (Chabukswar and Deodhar, 2005).

Effect of growth regulators: Different growth regulator treatments significantly influenced the performance of cuttings over control (Table 1). Rooting hormone IBA exhibited better results over NAA and other treatments. After one month the maximum number of sprouts (4.88) were recorded under treatment T₆, i.e., IBA 5000 ppm followed by T₅ (4.15), T₂ (4.20) and minimum in T₃ (1.53) treatment. After three months of planting maximum shoot length (22.93 cm), root (19.54 cm) and per cent survivability (73.0) was registered with IBA 5000 ppm treatment followed by IBA 2500 ppm and NAA 5000 ppm and least under control. The higher concentration of IBA gave better results as it helps in initiation of cell division and early root formation (Hartman *et al.*, 2002). Presented results are also in the line of Tripathi and Shukla (2004) and Ram *et al.* (2005) who used IBA-5000 ppm along with p-hydroxybenzoic acid (PHB) in pomegranate. Ghosh *et al.* (1988) also found that IBA was more effective than NAA in rooting on pomegranate stem cutting.

Combined response of growing media and growth regulators: The combination of media and PGRs significantly influenced different attributes of cuttings viz., number of sprouts, lengths of shoot and root, per cent survivability and root density. Combination of cocopeat + IBA 5000 ppm showed the maximum number of shoots (7.60), shoot length (26.70 cm), root length (25.60 cm) and survivability of cuttings (85 %) closely followed by cocopeat + IBA 2500 ppm and least under soil + no treatment (Fig. 2). Earlier, Gurjar and Patel (2007) studied all the root and shoot characters of pomegranate cv. Ganesh found that these were significantly increased with hardwood cutting planted in soil + sand + leaf mold medium and treated with IBA 4000 ppm. Torkashvand and Shadparvar (2012) found 4000 ppm IBA and coco peat-perlite substrate most effective for *Hibiscus rosa-sinensis* cuttings. Thus, hardwood cuttings of pomegranate cv. Bhagwa treated with IBA-5000 ppm and then planted in cocopeat based growing media showed better response (higher number of sprouts, lengths of shoot and root) and maximum establishment rate in terms of per cent survivability and root density.

Table 1. Response of different growing media and plant growth regulators on hardwood cuttings of pomegranate cv. Bhagwa.

Treatm ent	No. of Sprouts/cutting (1MAP)	Shoot length (cm) (3MAP)	Survivability of cutting (%) (3MAP)	Root length (cm) (3MAP)
Media				
M1	2.99 ^b	19.64 ^b	61.00 ^b	16.07 ^b

M2	5.54 ^a	21.35 ^a	74.17 ^a	19.48 ^a
M3	2.80 ^b	18.90 ^b	59.33 ^b	16.33 ^b
M4	2.45 ^c	14.28 ^c	51.17 ^c	9.67 ^c
Plant growth regulator				
T1	2.46 ^d	16.03 ^d	56.75 ^d	13.35 ^d
T2	4.20 ^b	18.18 ^c	65.25 ^c	14.78 ^c
T3	1.53 ^e	14.98 ^d	46.00 ^d	11.68 ^c
T4	3.46 ^c	18.05 ^c	58.50 ^c	14.88 ^c
T5	4.15 ^b	21.12 ^b	69.00 ^{ab}	18.13 ^b
T6	4.88 ^a	22.93 ^a	73.00 ^a	19.54 ^a

Table 2. Combined response of different growing media and plant growth regulators on root density*

Combination	Root density	Combination	Root density	Combination.	Root density	Combination	Root density
Vermiculite + NAA - 2500	M	Cocopeat + NAA - 2500	M	Sand + NAA - 2500	M	Soil + NAA - 2500	L
Vermiculite + NAA - 5000	M	Cocopeat + NAA - 5000	H	Sand + NAA - 5000	M	Soil + NAA - 5000	L
Vermiculite + Control	L	Cocopeat + Control	L	Sand + Control	L	Soil + Control	L
Vermiculite + Sarex	M	Cocopeat + Sarex	H	Sand + Sarex	M	Soil + Sarex	L
Vermiculite + IBA - 2500	H	Cocopeat + IBA - 2500	H	Sand + IBA - 2500	H	Soil + IBA - 2500	M
Vermiculite + IBA - 5000	H	Cocopeat + IBA - 5000	H	Sand + IBA - 5000	H	Soil + IBA - 5000	M

L- Low, M- Medium and H- High

*Two months after planting.

MAP= Month after planting

Means with the same letter are not significantly different

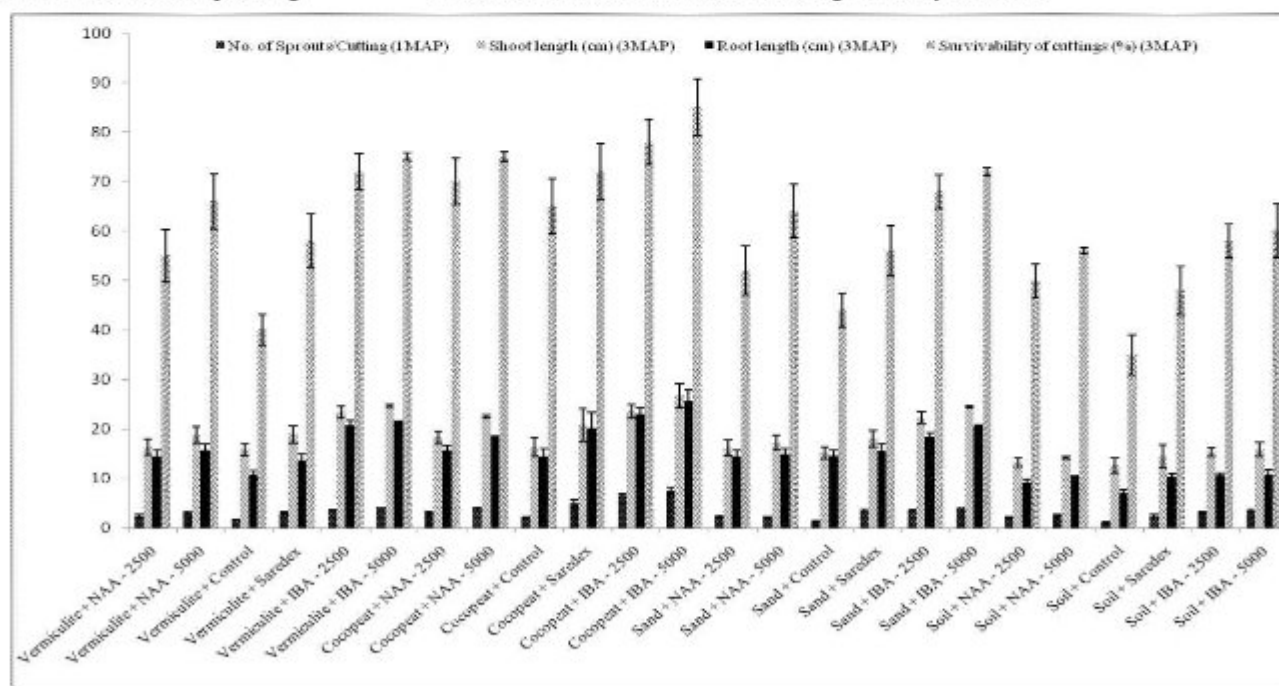


Fig. 1. Combined response of different growing media and plant growth regulators on hardwood cuttings of pomegranate cv. Bhagwa

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Effect of different varieties and FYM levels on yield and quality of onion (*Allium cepa* L.) in arid western Rajasthan

P.K. Kaswan*, P. K. Yadav, L.R. Jat and S.L. Khaswan¹
Department of Horticulture, College of Agriculture,
Swami Keshwanand Rajasthan Agricultural University, Bikaner-334 006

¹MPUAT, Udaipur

*Corresponding author's email: kaswanpk86@gmail.com

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Abstract:

An experiment was conducted during *rabi* season of 2009-2010 at Horticulture Farm, Swami Keshwanand Rajasthan Agricultural University, Bikaner. The experiment comprising of four varieties of onion viz., PDR, RO-59, RO-252 and RO-282 and FYM levels viz., 0, 20, 40 and 60 t ha⁻¹. A total of 16 treatment combinations were evaluated in randomized block design with three replications. The results indicated that plant height, number of leaves per plant, moisture content of bulb, neck thickness, diameter of bulb, volume of bulb, bulb yield, TSS and N, P and K uptake were maximum under the variety RO-252. Application of FYM @ 40 t/ha significantly increased number of leaves per plant, moisture content of bulb, neck thickness, diameter of bulb, volume of bulb, bulb yield, TSS, pungency and N, P and K content and uptake however, plant height at 60 DAT was maximum with the application of 60 t FYM/ha.

Key words: Bulb, Farm Yard Manure, moisture, onion, varieties and volume.

Introduction

Onion (*Allium cepa* L.) is one of the commonest and indispensable vegetable cum condiment crop grown for local consumption, export and processing and is used as salad and cooked in various ways in all curries, fried, boiled, baked, soup making and in pickles. Soils of Western Rajasthan, particularly in Bikaner district, contain very low clay (4-6%) and organic matter (0.08%), N (0.50%), P (0.25%) and K (0.50%). Farmyard manure rich in organic matter can be supplemented with N, P and K fertilizers. FYM not only provides most of the essential plant nutrients but also improves soil structure through binding effect on soil aggregates, Cation exchange capacity, water holding capacity, fertilizers use efficiency, microbial activity and nutrient availability in soil. Farm yard manure with chemical fertilizers and their method of application help in improving the fertility and productivity and physical condition of soil (Abusaleha and Shamugvelu, 1998). Among the various factors responsible for higher yield potential, the application of adequate quantities of Farm Yard Manure is considered as one of the most effective way to boosting the crop yield (Mohanty and Prusti, 2001 and Singh *et al.* 1995) in soils of western Rajasthan. The main

reason for low productivity is lack of suitable varieties for cultivation in arid areas. Most of the farmers are illiterate and always remain under confusion about recommended varieties. One of the important aspects of improvement in yield and quality of onion is the selection of suitable cultivars to a particular agro-climatic region.

Material and methods

The experiment was conducted on loamy sand soil at Horticulture Farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner, during *Rabi* season 2009-2010. The experiment comprising four varieties of onion viz., PDR, RO-59, RO-252 and RO-282 and FYM levels viz., 0, 20, 40 and 60 t/ha. A total of 16 treatment combinations were evaluated in randomized block design with three replications. The seven week old seedlings of four varieties of onion viz., PDR, RO-59, RO-252 and RO-282 were transplanted with spacing of 15 x 10 cm in second December 2009. The irrigation was applied through drip system consisted of 16 mm laterals having drippers at 40 cm distance. Each plot consisted of 3 laterals at 80 cm apart and four rows of onion were planted at each lateral. As per treatment FYM was applied at the time of field

preparation and chemical fertilizers i.e. nitrogen, phosphorus and potassium (100, 50 and 100 kg/ha) were applied through Urea, DAP and MOP.

Result and Discussion

Effect of varieties

Among different varieties, RO-252 produced significantly higher plant height and maximum number of leaves per plant at 60 days after transplanting over rest of the varieties (Table 1). Plant height and number of leaves per plant are the genetic characters and hence different varieties varied with respect to these characters which ultimately brought about variation in these characters. This finding corroborate with the results of Mohanty and Prusti (2001). RO-252 variety produced significantly higher moisture content of bulb. This might be due to characteristics of this variety that increased vegetative growth in terms of plant height and number of leaves per plant which resulted in higher moisture content of bulb. These characters play a vital role in various metabolic processes primarily that results in increased net photosynthesis and helps in the translocation of photosynthates in storage organ of bulb resulting in increased weight of bulb. Diameter and volume of bulb and bulb yield were found significantly higher in RO-252 however, significantly lesser neck thickness was found in same variety. This might be due to characteristics of these varieties that increased vegetative growth with extended frame work of plant. The bulb yield, being primary functions of cumulative effect of these parameters. Improved fresh weight of leaves and bulb with varietal characters leading to significant improvement in bulb yield and resulted in better source and sink relationship. Similar results were observed by Khar *et al.* (2007) in onion. Allyl-propyl disulphide was recorded highest in PDR variety than the other varieties of onion (Table 2). This might be due to characteristics of this variety that slightly increased trend leads to increase of volatile and fatty oil content resulting in significantly higher production of allyl-propyl disulphide in onion bulbs. Increased in allyl-propyl disulphide with variety PDR was in close agreement with those of Abbey *et al.* (2005) in onion. Highest TSS content (12.03 °Brix) was recorded in RO-252 variety of onion followed by RO-59, RO-282 and PDR which was 2.82, 2.99 and 6.64 per cent higher over RO-59, RO-282 and PDR, respectively. However, there was non-significant difference observed between RO-59 and RO-282. The varietal character increased total soluble solids, nitrogen, phosphorus and potassium content and uptake which were found maximum in RO-252. This might be due to vigorous vegetative growth and imparts deep green colour of the foliage which favoured photosynthetic activity of the plants. Due to this there was

greater accumulation of food material i.e. carbohydrate in the bulb. There was more synthesis of T.S.S. Similar observations were also reported by Khar *et al.* (2007) and Zhong *et al.* (1997) in onion.

Effect of FYM

The maximum plant height at 60 DAT was observed with the application of 60 tonnes FYM (Table 1). However, the maximum number of leaves per plant were recorded with FYM 40 t/ha. This might be due to the fact that application of FYM resulted in vigorous vegetative growth of the plant and imparted dark green colour to the foliage which favoured photosynthetic activity of the plant and greater synthesis of carbohydrate in the leaves leading to formation of amino acids, nucleo-proteins, chlorophyll, alkaloids and amides. These complex compounds are responsible for building up of new tissues and are associated with a number of metabolic processes, which in turn favoured better development of plant. These results are in agreement with the findings of Rafi *et al.* (2002) in tomato, Ghuge *et al.* (2007) also observed better growth in cabbage with organic manure application. Mallangouda *et al.* (1995) reported application of FYM and NPK improved plant height and number of branches in chilli. Manolika *et al.* (2007) reported that the application of farm yard manure 40 t/ha along with 50% RDF produced maximum height of plant in tomato.

In general, the significant improvement in yield attributes of onion with the farm yard manure could be ascribed to overall improvement in vigour and crop growth as already explained in preceding paragraphs. Since an adequate and small amount of major nutrients supplied through FYM in the life of a plant is considered important in promoting rapid fresh weight and dry weight of bulb in terms of bulb size, diameter of bulb, volume of bulb and bulb yield. These parameters were recorded significantly higher with application of 40 tonnes FYM per hectare. FYM coupled with increased net photosynthesis and helps in the translocation of photosynthates in storage organ of bulb resulted in increased diameter and weight of bulbs (Singh *et al.* 1995 and Mallangouda *et al.* 1995). The bulb yield being a primarily function of cumulative effect of these parameters, significantly increased by 315.17 q/ha with FYM at 40 t/ha.

The beneficial effects of farm yard manure on yield attributes were probably due to enhanced supply of macro as well as micronutrients during entire growing season. It might have attributed to higher manufacture of food and its subsequent partitioning in sink. The availability and supply of nutrients to plants favourably influenced the flowering and fruit formation, ultimately increased the bulb yield. The FYM might enhance the efficiency of uptake of native and soil nutrients. The reason for increased bulb yield with the

application of farm yard manure could be attributed to solubilization effect of plant nutrients by the addition of FYM leading to increased uptake of nutrients especially NPK as reported by Raina and Jaggi (2008) in onion and Singh and Janardan (2004) in potato. The improvement in bulb weight and yield of onion in response to farm yard manure application is possibly attributed to improved soil physical conditions and slow release availability of nutrients (Dimri and Singh, 2005).

The application of farm yard manure up to 40 t/ha significantly increased the total soluble solids (TSS) content in comparison to control and other doses of FYM (Table 2). The maximum TSS in bulb was recorded with FYM @ 40 t/ha. The improvement in TSS might be due to the known fact that organic manures (farm yard manures) are capable of supplying adequate macro and micro plant nutrients which play a major role in quality improvement through desirable enzymatic changes taking place during growth. Higher nutrient contents in leaves and bulb also seems to be attributed to higher functional activity of roots for lower duration under this treatment. Similar results were obtained by Gupta *et al.* (1999) and Bairwa *et al.* (2009). The pungency of onion increased with the increasing doses of FYM up to 60 t/ha than the control. The increase in

pungency of onion at higher level of FYM was due to increase in synthesis and translocation of sulphur to the onion (Raina and Jaggi, 2008).

Application of 40 t FYM/ha significantly increased the nitrogen, phosphorus and potassium contents and uptake in plants over its lower doses but remained at par with 60 t FYM/ha. The positive influence of FYM on N, P and K contents in plants was due to improved nutritional environment in the dense root zone of the plants. Thus adequate supply of FYM early in the crop season resulted in greater availability of nutrients including N, P and K in particular root zone. Nutrient availability increased in the root zone coupled with increased metabolic activity at the cellular level might have increased the nutrients uptake and accumulation in vegetative plant parts. The NPK uptake increased under organic treatments as compared to control. The probable reason for this increase was that, sources of organic manures applied to onion might have improved nutrient availability in soil and thus benefited the crop. Secondly, higher bulb yield obtained with organic sources also resulted in better uptake of nutrients from soil. Higher uptake at maximum fertility level might be due to more nutrient content and yields which removed more nutrients from soil (Sarkar and Mondal, 2005).

Table 1. Effect of varieties and FYM levels on growth and yield of onion.

Treatments	Plant height (cm) at 60 DAS	No. of leaves per plant at 60 DAS	Moisture content of bulb (%)	Neck thickness (cm)	Diameter of bulb (cm)	Volume of bulb (cc)	Bulb yield (q ha ⁻¹)
Varieties							
PDR (V ₁)	54.45	6.5	11.27	1.53	4.69	53.73	251.88
RO-59 (V ₂)	54.43	6.85	15.99	2.01	5.06	55.58	268.14
RO-252 (V ₃)	56.17	7.15	18.21	2.28	5.34	57.98	290.49
RO-282 (V ₄)	53.98	7.05	16.39	2.13	5.22	54.90	258.39
S. Em +	0.51	0.07	0.43	0.04	0.10	0.80	5.63
C.D. at 5%	1.48	0.21	1.25	0.11	0.28	2.31	16.27
Levels of FYM (t/ha)							
Control (F ₀)	51.87	6.53	13.2	1.64	3.68	40.78	182.18
20 (F ₁)	53.7	6.7	15.13	1.94	4.63	55.13	242.01
40 (F ₂)	55.53	7.07	16.26	2.14	5.87	62.47	315.17
60 (F ₃)	57.93	7.25	17.27	2.23	6.13	63.82	329.53
S. Em +	0.51	0.07	0.43	0.04	0.10	0.80	5.63
C.D. at 5%	1.48	0.21	1.25	0.11	0.28	2.31	16.27

Table 2. Effect of varieties and FYM levels on quality parameters of onion

Treatments	TSS (°Brix)	Allyl-propyl disulphide content (mg/100g)	Nutrient content (%)			Nutrient uptake (kg/ha)		
			Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
Varieties								
PDR (V ₁)	11.28	5.59	0.860	0.581	0.985	23.92	16.30	27.36
RO-59 (V ₂)	11.70	5.34	0.879	0.628	0.979	25.94	18.64	28.80
RO-252 (V ₃)	12.03	5.32	0.880	0.646	0.992	27.92	20.51	31.45
RO-282 (V ₄)	11.68	5.44	0.865	0.654	0.995	24.72	18.71	28.28
S. Em +	0.11	0.05	0.005	0.007	0.002	0.55	0.43	0.55
C.D. at 5%	0.31	0.15	0.013	0.021	0.006	1.60	1.25	1.59
Levels of FYM (t/ha)								
Control (F ₀)	10.98	5.18	0.843	0.586	0.974	17.44	12.14	20.12
20 (F ₁)	11.53	5.37	0.862	0.621	0.984	23.04	16.60	26.27
40 (F ₂)	11.94	5.51	0.887	0.648	0.996	30.29	22.11	33.96
60 (F ₃)	12.23	5.62	0.891	0.654	0.998	31.73	23.31	35.54
S. Em +	0.11	0.05	0.005	0.007	0.002	0.55	0.43	0.55
C.D. at 5%	0.31	0.15	0.013	0.021	0.006	1.60	1.25	1.59

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Observations on the pioneer white butterfly, *Belenois aurota* (Lepidoptera: Pieridae) in Ker (*Capparis decidua*) plant in Arid region of India

S.M. Haldhar¹, G. T. Behere², R. Bhargava¹, R. S. Singh¹, H. Krishna¹, G. L. Jat¹ and D. Singh¹

¹ICAR- Central Institute for Arid Horticulture, Bikaner-334006, Rajasthan, India

²ICAR Research Complex for NEH Region, Umroi Road, Umiam-793103, Meghalaya, India

*Corresponding Author email : haldhar80@gmail.com

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Abstract

The pioneer white butterfly, *Belenois aurota* Fabricius, 1793 (Lepidoptera: Pieridae), has found to be emerging as a major pest of ker (*Capparis decidua*) plant in arid region of India and causes over 70% damage to wild and cultivated ker plants. During the survey of pest incidence, the maximum incidence (86.67%) was observed in first fortnight of December and it was reduced to 11.67% in first fortnight of September in subsequent year. The average numbers of insects ranged between 1.33 to 10.33 larvae per branch of plant. Adults of this small butterfly were blacks and whites in color with black markings on both upper and under sides broader, the white spots on black apical area of fore wing often sub-obsolete above. Eggs were laid in batches on young shoots or new branches and were 1.74 mm in length, 1.55 mm in width and yellow in color when first laid. The length and width of 1st instar larvae were 2.05 mm and 0.47 mm, respectively and feed on branches gregariously. There were total of five instars. Pupae were 18.84 mm long and 4.92 mm wide. Adult females had a body length of 13.23 mm and a wingspan of 41.65 mm. Bodies of males were 11.54 mm long and their wingspan measured 38.72 mm.

Key words: *Belenois aurota*; *Capparis deciduas*; incidence; morphological characterization

Introduction

Capparis decidua (Forsk.) Edgew (Capparidaceae), locally known as ker, is a drought resistant plant growing in dry regions of India as dense tufts. It is a small much branched tree or shrub of arid regions in Africa, Middle East and southern Asia, including the Thar Desert. It bears a mass of slender, leafless branches, the small caduceus leaves being found only on young shoots. It rarely exceeds a height of 5 meters. The new flush of leaves appears in November–January. Red conspicuous flowers appear in March to April and August–September and ripe by May and October. The pink fleshy berries are readily eaten by birds. It coppices well and produces root suckers freely. It is extremely drought-resistant and tolerates some frost (Burdak, 1982). This is a very useful plant in its marginal habitat. Their spicy fruit are used for preparing vegetables, curry and fine pickles and can attract helpful insectivores and is also used in folk medicine and herbalism. *C. decidua* can be used in landscape gardening, afforestation and reforestation in semi desert and desert areas; it provides assistance against soil erosion (Kaul, 1963). The green immature fruits are considered antihelminthic and laxative and are employed in

the treatment of asthma, constipation, coughs, hysteria and other psychological problems (Ghazanfar, 1994).

There are 30 species in the genus *Belenois*, distributed variously across Africa, Arabia, the Indian subcontinent, south-east Asia and Australia (Chandra, 1985; Kunte, 2006; Ghosh and Saha, 2016). *Belenois aurota* Fabricius, 1793 has a wide distribution range extending across sub-Saharan Africa (including Madagascar) and Arabia to the Indian subcontinent, and also occurs in north of the Himalayas in Turkmenia and Tajikistan. *B. aurota* has been reported from India, but basic information on damage, incidence, morphometric analysis and its molecular data is lacking (Woodhall, 2005; Kunte, 2006; Nimbalkar *et al.*, 2011). As per the existing primary literature scan and to our knowledge, the pest status of *B. aurota* has not been reported, and therefore, we believe that this would be of first study of such kind where all the comprehensive information is available at one place. Furthermore, proper management strategies of an emerging pest are largely based on better understanding of their damage, incidence and morphometric analysis. The

information reported in this study would be helpful for biological studies of this pest species.

Material and Methods

Species identification and morphometric measurements

The dried and pinned adult specimens were sent to Insect Biosystematic Section, Division of Entomology, Indian Agricultural Research Institute, New Delhi for taxonomical identification. The average linear measurements of various body parts of male and female adults were obtained under a binocular microscope (Radical Instruments, Ambala, Haryana, India) using Jenoptic Pro 2.8.0 software. Twenty insects (10 males and 10 females) were used for observation and measurements. The larvae were reared under laboratory conditions (temperature at $28 \pm 2^\circ\text{C}$ with a relative humidity of $60 \pm 5\%$) for measurement of different stages. The terminology used to denote different parts of the body were according to Haldhar (2012), Haldhar and Singh (2014) and Haldhar *et al.* (2015). The illustrations were scanned at 600 dpi black and white, and mounted onto plates by Adobe Photoshop 8.0.

Incidence and symptoms

Twenty ker plants were selected randomly in each of 3 replicates at the Experimental Farm of the Central Institute for Arid Horticulture (CIAH) ($N 28^\circ 06' E 73^\circ 21'$). Incidence of infestation observed on each plant and numbers of larvae per branch was recorded 15 days interval from September 2013 to March 2014 and September 2014 to March 2015. The sampling was done by visual observation and manual counting. Average incidence was calculated as the percentage of whole plants infested by *B. aurota*. Average numbers of larvae per branch was calculated from numbers recorded for 10 randomly selected ker plants with 3 replications.

Statistical analysis

Before statistical analysis, data were transformed as necessary to achieve normal distribution. The data on incidence and numbers of insects were analyzed by 1-way ANOVA using SPSS software (O'Connor, 2000). When significant differences were detected, means were compared by using Turkey's honest significant difference (HSD) tests for paired comparisons at a probability level of 5%.

Results

Incidence and symptoms

For the first time, pioneer white butterfly was observed on ker plant in the hot arid region of north-western India, (*i.e.*, Thar Desert) and identified as *B. aurota*. During the present study, the average incidence of butterfly larvae

on plants ranged between 11.67 and 86.67 per cent (Table 1 & Fig. 1). The incidence and the numbers were higher in winter months (November to January) and the maximum incidence of 85.00 and 86.67 per cent was recorded in first fortnight of December and the minimum 11.67 and 13.33 per cent in first fortnight of September during 2013-14 and 2014-15, respectively. Thus the highest mean number of this butterfly species per branch was recorded in first fortnight of December (10 & 10.33/ branch) and the lowest was in second fortnight of March (1.33 & 1.67/ branch) during 2013-14 and 2014-15, respectively (Table 1). Due to attack by this pest, the growth of ker plants was suppressed and new branches and leaves wilted and dry. On hatching, clusters of young larvae feed gregariously by initially scraping the surface of the branches and leaf. Later instars disperse and move on to other branches and leaves and feed voraciously, producing large irregular holes and may leave only the veins. High infestation causes severe defoliation. This larvae quickly skeletonised branches and leaves as they attack in clusters in early stages.

Morphometric measurements

Data on linear measurements of *B. aurota* have been presented in Tables 2 and 3 and Fig. 2. This butterfly was typically characterized as males white, front wings black tipped with white spots, white margin to hind wings and female similar but the black markings on both upper and under sides broader, the white spots on black apical area of fore wing often sub-obsolete above. The adult females had a body length of 13.23 mm and a wingspan of 41.65 mm. The male body length and wingspan were 11.54 mm and 38.72 mm, respectively. Antennae in both sexes black sparsely sprinkled with white dots. The lengths of male and female antennae were 10.54 mm and 11.40 mm, respectively. The female length of fore wing, hind wing, head, thorax, abdomen, proboscis, fore, middle and hind legs were 19.23, 16.32, 1.65, 4.83, 9.15, 8.95, 6.53, 7.44 and 8.02 mm, respectively. The male width of fore wing, hind wing, head, thorax and abdomen were 10.31, 11.15, 2.48, 2.36 and 2.16 mm, respectively. Eggs were laid in batches on branches or young shoots. They were 1.74 mm in length, 1.55 mm in width, and yellow in color when first laid. When hatched, the 1st larval instar was olive colour with a distinct glossy jet-black head. The length and width of 1st instar larvae were 2.05 and 0.47 mm, respectively. The lengths of 2nd, 3rd, and 4th instar larvae were 5.12, 12.27, and 18.60 mm, respectively. The 5th instar larvae were 24.71 mm long, 3.93 mm wide, and long, cylindrical, broader towards the head, slightly tomentose on back, hairy on the sides. Pupae were 18.84 mm long, 4.92 mm wide, and transparent, pale cream-colour. In front of pupa a longish tubercle with a black mark on each side, a lateral line of pale plum-colour on which is a longitudinal line of yellow round dots and a transverse row of dots on each segment.

Discussion

To our knowledge this is the first report of *B. aurota* as pest damage, incidence, morphometric analysis and its DNA barcoding evidence of ker from World. The incidence and the numbers were higher in winter months (November to January) as compare to other seasons and the maximum incidence was recorded in first fortnight of December and the minimum in first fortnight of September. Chandra *et al.* (2000), Wynter-Blyth (1957) and Ghosh and Saha (2016) reported that the host *Capparis aphylla*, *C. sepiaria*, *C. heyneana*, *Cadaba indica* and *Maerua arenaria* of pioneer white butterfly *A. aurota*. This butterfly was typically characterized as males white, front wings black tipped with white spots, white margin to hind wings and female similar but the black markings on both upper and under sides broader, the white spots on black apical area of fore wing often sub-obsolete above. Sharma (2014) and D'Abrera (1982) described the morphometric of *A. aurota* as adult upperside male pure white with black apex in the

forewing and black outer margins in both wings. Black area with white spots, elongated in the forewing and rounded in the hindwing. Female similar to male, but with thicker and broader veins, apex and outer margins. Underside male spots in the apex, yellowish in the forewing and yellow with black veins in hindwing. Wingspan 50-60 mm. It is distributed throughout India except Assam. It is also found in Afghanistan, Africa, a few Mediterranean countries, Bhutan, Pakistan, Saudi Arabia, Iran, Asia Minor, Madagascar, Myanmar and Australia (Kunte, 2006; Chandra, 1985; Ghosh and Saha, 2016).

In published literature no incidence and linear morphometric details given on *B. aurota* could be found; and the first incidence and linear morphometric study of *B. aurota* is described herein. This butterfly was damaging economically important parts of plant, such as leaves and branches. Therefore, management practices needs to be developed and implemented to minimize the losses caused by this pest.

Table 1. Percent infestation and number of larvae per branch of butterfly, *Belenois aurota* on *Capparis decidua* during 2013-14 and 2014-15

Sampling month	Mean incidence (%) ^{a,b}		Mean no. of <i>B. aurota</i> larvae per branch ^b	
	2013-14	2014-15	2013-14	2014-15
September-I*	11.67 (19.88) ^a	13.33 (21.33) ^a	2.33 ^{ab}	2.67 ^{bc}
September-II	16.67 (24.04) ^{ab}	18.33 (25.30) ^{ab}	2.67 ^{bc}	3.00 ^c
October-I	28.33 (32.13) ^c	30.00 (33.15) ^c	4.67 ^{def}	5.00 ^{efg}
October-II	43.33 (41.15) ^d	45.00 (42.10) ^d	5.67 ^f	6.00 ^g
Nov-I	53.33 (46.89) ^e	55.00 (47.86) ^{ef}	7.33 ^g	7.67 ^h
Nov-II	65.00 (53.74) ^{fg}	66.67 (54.73) ^g	7.33 ^g	7.33 ^h
Dec-I	85.00 (67.38) ^h	86.67 (68.64) ⁱ	10.00 ^h	10.33 ⁱ
Dec-II	81.67 (64.67) ^h	85.00 (67.38) ⁱ	7.67 ^g	8.00 ^h
Jan-I	73.33 (58.91) ^g	76.67 (61.12) ^h	5.33 ^{ef}	5.67 ^{fg}
Jan-II	61.67 (51.73) ^f	63.33 (52.72) ^{fg}	5.00 ^{def}	5.33 ^{efg}
Feb-I	60.00 (50.77) ^{ef}	60.00 (50.77) ^{ef}	4.33 ^{cde}	4.67 ^{def}
Feb-II	45.00 (42.10) ^d	48.33 (44.02) ^{de}	4.00 ^{cd}	4.33 ^{de}
March-I	21.67 (27.70) ^{bc}	23.33 (28.77) ^{bc}	3.33 ^{bc}	3.67 ^{cd}
March-II	15.00 (22.59) ^a	16.67 (24.04) ^{ab}	1.33 ^a	1.67 ^{ab}
CD	4.45	4.93	1.18	1.25

* I means first fortnight of month and II means second fortnight of month.

^a Parentheses contain the angular transformation value.

^b Values followed by different letters are significantly different (Tukey's HSD test, $P < 0.05$).

Table 2. Linear morphometric measurements of different life stages of the butterfly, *Belenois aurota*

Life stage	Length (mm) Mean* $\pm$ SE	Width (mm) Mean* $\pm$ SE
Egg	1.74 $\pm$ 0.012	1.55 $\pm$ 0.007
1st instar larva	2.05 $\pm$ 0.010	0.47 $\pm$ 0.004
2nd instar larva	5.12 $\pm$ 0.020	1.05 $\pm$ 0.010

Life stage	Length (mm) Mean* $\pm$ SE	Width (mm) Mean* $\pm$ SE
3rd instar larva	12.27 $\pm$ 0.024	1.94 $\pm$ 0.013
4th instar larva	18.60 $\pm$ 0.032	2.83 $\pm$ 0.025
5th instar larva	24.71 $\pm$ 0.037	3.93 $\pm$ 0.020
Pupa	18.84 $\pm$ 0.032	4.92 $\pm$ 0.014
Adult female with wingspan	13.23 $\pm$ 0.020	41.65 $\pm$ 0.090
Adult male with wingspan	11.54 $\pm$ 0.028	38.72 $\pm$ 0.061

* Mean of ten specimens.

Table 3. Linear morphometric measurements of various traits of adult males and females of butterfly, *Belenois aurota* infesting

Capparis decidua

Body parts measured (mm)	Male	Female
	Mean $\pm$ SE	Mean $\pm$ SE
Length of fore wing	18.33 $\pm$ 0.040	19.23 $\pm$ 0.023
Width of fore wing	10.31 $\pm$ 0.021	12.01 $\pm$ 0.016
Length of hind wing	14.15 $\pm$ 0.019	16.32 $\pm$ 0.015
Width of hind wing	11.15 $\pm$ 0.022	12.30 $\pm$ 0.027
Length of head	1.46 $\pm$ 0.007	1.65 $\pm$ 0.007
Width of head	2.48 $\pm$ 0.009	2.75 $\pm$ 0.008
Length of thorax	4.10 $\pm$ 0.010	4.83 $\pm$ 0.012
Width of thorax	2.36 $\pm$ 0.006	2.83 $\pm$ 0.013
Length of abdomen	8.45 $\pm$ 0.009	9.15 $\pm$ 0.011
Width of abdomen	2.16 $\pm$ 0.005	2.65 $\pm$ 0.008
Length of proboscis	7.74 $\pm$ 0.013	8.95 $\pm$ 0.006
Length of antenna	10.54 $\pm$ 0.020	11.40 $\pm$ 0.013
Length of fore leg	5.59 $\pm$ 0.013	6.53 $\pm$ 0.010
Length of middle leg	6.71 $\pm$ 0.017	7.44 $\pm$ 0.010
Length of hind leg	7.11 $\pm$ 0.015	8.02 $\pm$ 0.013



Figure 1. Damage symptoms of *Belenois aurota* on ker (*Capparis decidua*) during the winter season at the ICAR-Central Institute for Arid Horticulture, Bikaner, India.



Figure 2. Different developmental stages of *Belenois aurota*. A, eggs; B, 1st instar larvae; C, 5th instar larva; D, pupae; E, adult male; F, adult female.

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SHORT COMMUNICATION

Scenario of *ber* fruit weevil *Aubeus himalayanus* Voss (Coleoptera: Curculionidae) incidence in *ber*-based cropping system

V. Karuppaiah^{*,†}, P.L. Saroj and Hare Krishna

Central Institute for Arid Horticulture, Bikaner Rajasthan, India - 334006

[†] Present address: Directorate of Cashew Research, Puttur, Karnataka.

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The *ber* fruit weevil, *Aubeus himalayanus* is an emerging pest of *ber* in arid and semi-arid region of India. It was recorded as a new pest of *ber* for the first time from Andhra Pradesh (Gour and Sriramulu, 1994). Later, from Rahuri, Maharashtra and Jobner, Rajasthan Anonymous (2003) Karnataka (Balikai *et al.*, 1998) and lately in Bikaner (Karuppaiah *et al.*, 2010). The pest infestation occurs in all the fruit stages; however, it is prevalent in pea to pebble size fruits. Pest feeds only on the seed of developing fruit and arrests further fruit development. In severe cases it could causes damage up to 23.63% to 43.28% (Karuppaiah *et al.*, 2014). Currently fruit weevil is managed mainly using synthetic insecticides and usage of bio-pesticides is very limited. Summer ploughing, is an ecologically sound cultural method in minimizing the fruit weevil, which destroy the residual pupa and it is also a recommended cultural practice against tephritid fruit flies of *ber*.

The intercropping of annual crops in between perennial fruit crops is a regular farming practice in arid region to achieve more monetary return in a unit area per time. Growing annual crops like cluster bean and green gram between the *ber* rows as intercrops is a common and suggested practice under arid ecosystem as it increased on an average of 10% higher monetary returns over sole *ber* system (Patel *et al.* 2003). Moreover, in the context of ecological pest management growing of non-host or pest repelling plants could be promising intervention to check the pest intensity in main crop. Intercrop also manipulates confusing environment and acts as repellents to arthropods to find its host. This could supplement to curb the pests menace and also boost the natural enemy populations (Lal *et al.*, 2002). The possible alteration in microclimate and site-specific allelopathic interaction surrounding vegetation led the changes in incidence of insect pests and natural enemies. Though ample work has been done on production aspects of *ber* based intercropping model/system but no work is

carried out to document the status of insect pests of *ber*. Since, *ber* fruit weevil is an emerging pest to this region; the present study was conducted to study the status of fruit weevil incidence in *ber* based intercropping model under hot arid ecosystem.

The observations were made on 10 year old trees of *ber* cv. Gola in the Experimental Block of Central Institute for Arid Horticulture, Bikaner, Rajasthan. Six treatments viz., *ber* + radish, *ber* + mustard, *ber* + coriander, *ber* + marigold, *ber* + barley and *ber* (sole crop as control) were imposed with randomized block design in three replications. Sowing of annual crops was done during Rabi 2008-09. Treatments were also imposed in three different spacing environments viz., 16 m x 12 m, 8 m x 8 m and 6 m x 6 m in the *ber* block, specially, developed to conduct the *ber* based farming system for hot arid environment. The recommended agronomic practices were carried out for both main crop (*ber*) and intercrops. The data on incidence of fruit weevil were recorded from first fortnight of October to till harvest. The observation was taken from randomly selected three branches/ treatment at fortnight interval. The per cent incidence was computed by subtracting total infested fruits with total number of fruits per branch. The data were analyzed with standard statistical package.

The incidence of fruit weevil in five different intercrop combinations was presented in the Table 1. The significant different was observed among the different set of combination. The least incidence of stone weevil was observed in *ber* where no intercrop was done and per cent damage was 7.42, 7.23, and 7.21 in 16 x 12, 8 x 8 and 6 x 6 m spacing environment, respectively. Apart from sole *ber*, in the plantation with 16 x 12 m spacing, *ber* + radish combination registered low fruit weevil incidence (7.52%) followed by *ber* + coriander (7.79%), *ber* + mustard (10.50%), *ber* + barley (10.51%) and *ber* + marigold (11.73%). At 8 x 8 m plantation least damage of weevil

recorded in *ber* + barley (10.46%) combination followed by *ber* + coriander (13.22%), *ber* + marigold (14.80%), *ber* + radish (18.39 %) and maximum with *ber* + mustard (20.37%). At 6 x 6 m spacing the least damage of fruit weevil noticed in *ber* + barley (10.33%) followed by *ber* + marigold (12.83%), *ber* + coriander (19.67%), *ber* + mustard (26.96%) and *ber* + radish (32.82%). Irrespective of different planting space, the maximum infestation of 19.58% damage was recorded in *ber* + radish combination. The infestation trend was *ber* + radish > *ber* + mustard > *ber* + coriander > *ber* + marigold > *ber* + barley > *ber* (sole). Overall among the intercrop combinations *ber* + barley combination found to be promising in reducing the weevil incidence with both of the models viz, 8 x 8 and 6 x 6 m (Fig 1). Irrespective of intercrop combination, the greater incidence of stone weevil recorded with the closer planting model i.e. 6 x 6 m followed by 8 x 8 m and 16 x 12 m and mean damage was 13.03, 13.74 and 14.80 per cent, respectively (Fig 2). However statistically no significant in damage level was observed between the planting system.

Intercropping affects the pests by changing microclimate through change in canopies and physical factors (Goel and Tiwari, 2004); diverted orientation due to alteration in crop architecture (Elanchezhyan and Baskaran *et al.*, 2008) and poly-culture create plant diversity, which affects the population dynamics of insect pests (Sinha *et al.*, 2007). However, in the present study, the fruit weevil

damage was significantly low in sole *ber* (control) where no annual crop was planted. This might be due to non availability of favourable microclimate for fruit weevil activity in and around *ber* tree. Growing intercrop could have been provided favorable humidity and shade for survival and population buildup of fruit weevil. On the other hand, studies were reported that growing non host plants in between the annual crops helps in reducing the target pest, which is mainly through repellent mechanism prevails in the intercrop. The crop, marigold was found promising, while coriander found to be encouraging in reducing *ber* fruit fly infestation under *ber* based intercropping model (Karuppaiah *et al.*, 2014). Similarly, studies also established that marigold repelled mexican bean beetle in bean, coriander repelled aphids in rose (Kianmatee and Ranamukharachchi, 2007) and low stem gall incidence on cotton in combination of cotton with marigold (Vaiyapuri *et al.*, 2007).

Our results conclude that, intercropping of non host annual crops in between the *ber* plantation may add the monetary return but could facilitate the fruit weevil incidence. However, in the view of *ber* based intercropping model, the combination model, *ber* + barley would be a better combination model that could minimize the stone weevil incidence than the other combination tried in this study.

Table 1. Mean damage (%) of *ber* fruit weevil, *Aubeus himalayanus* Voss on *ber* based intercropping system

Treatments	Environments (spacing)		
	16 m x 12 m	8 m x 8 m	6 m x 6 m
T1- <i>Ber</i> + radish	7.52 (2.43)	18.39 (3.53)	32.82 (4.61)
T2- <i>Ber</i> + coriander	7.79 (2.44)	13.22 (2.99)	19.67 (3.69)
T3- <i>Ber</i> + marigold	11.73 (2.83)	14.80 (3.21)	12.83 (3.07)
T4- <i>Ber</i> + mustard	10.50 (2.77)	20.37 (3.69)	26.96 (4.24)
T5- <i>Ber</i> +barley	10.51 (2.83)	10.46 (2.80)	10.33 (2.68)
T6- <i>Ber</i> (sole)	7.42 (2.20)	7.23 (2.27)	7.21 (2.40)
SEd	0.13	0.24	0.43
CD (0.05)	0.30	0.54	0.95
^a bt/w intercrop combinations			

Figure in parenthesis are *sqrt* transformed values

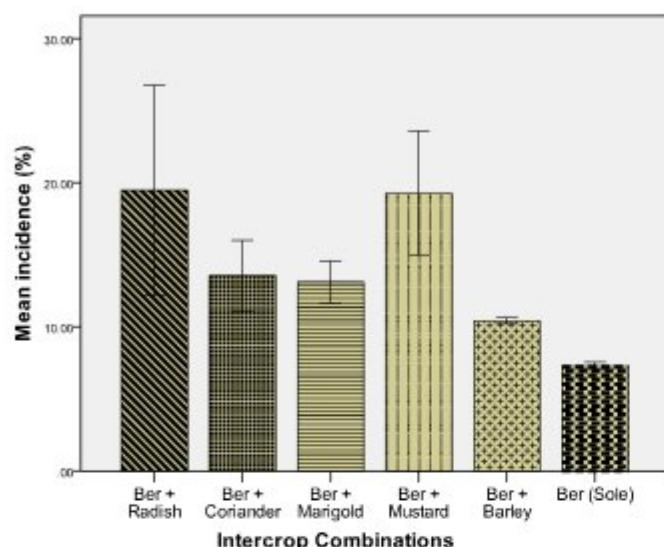


Figure 1. Incidence level of fruit weevil, *Aubeus himalayanus* Voss in different intercrop combination

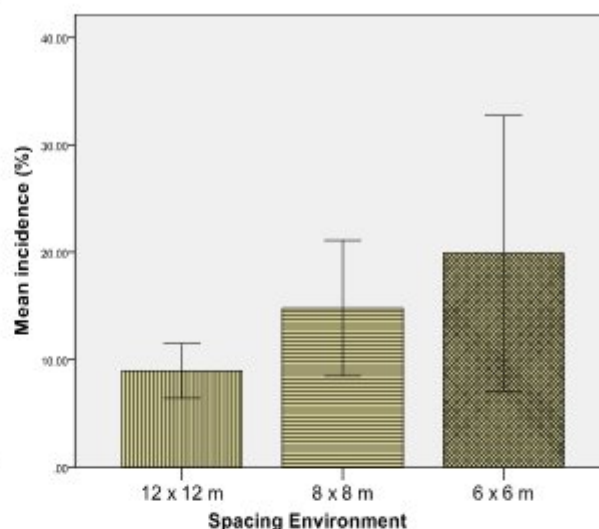


Figure 2. Incidence level of fruit weevil, *Aubeus himalayanus* Voss in different plant planting system

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Leaf sampling technique of wood apple (*Feronia limonia*)

Abhiskta Khan and S.N. Ghosh*

Department of Fruits and Orchard Management, Faculty of Horticulture,
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal-741252

*Corresponding author's email : profsnghosh@yahoo.co.in

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The wood apple (*Feronia limonia* Swingle) is a theory deciduous underutilized fruit tree, belonging to family Rutaceae, found mainly in the forest and as individual 'stray plant' in unused neglected area. The ripe fruit contains sweet aromatic pulp which has high neucentric properties. Its leaves, roots and bark possess medicinal properties. The trees are grown without much care and application of manures and fertilizers are rarely applied. At present, necessity of nutrient-feeding in underutilized fruit trees through organic manures and chemical fertilizers for sustainable production of quality fruits has been well recognized (Ghosh, 2014, Ghosh and Bera, 2014, Sharath and Ghosh, S.N. 2015). NPK are the major nutrients required by any fruit crop in a larger amount which vary according to age, soil status and climatic conditions prevailing in the area. To study the nutritional status of a plant, leaf analysis is considered as one of the realistic tool or method (Bhargava, 1999) where foliar N, P, K values could indicate the status of plant health and productivity (Ghosh, 2014). For knowing values of N, P and K in leaves, time of its collection, i.e. maturity of leaves, is very important. Besides maturity, position of leaves in the plant from where it will be collected, is another aspect of leaf collection. No such data is available in these aspects and therefore an investigation was made in this direction.

The experiment was conducted at the Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal on 7 year old mature trees of wood apple during 2014-2015. The soil of the experimental orchard was collected before starting of the experiment and analyzed. The soil was sandy loam having surface soil pH 6.80 and available N, P and K were 230.00, 35.20 and 86.0 kg/ha respectively.

For estimation of N, P and K, the newly emergent leaves were tagged randomly in selected 4 trees for monthly collection. The leaves emerged in April that collected in May, was considered as one month old and thus, age of leaves was calculated. In each time 40 leaves/tree in four directions was collected for estimation of N, P and K. After knowing the results of the first year, the leaves were

collected from the tagged branches of bottom, middle and top portion of the plant on the basis of plant height in the month of August and September (4-5 month old leaves) during the next year. Leaf N was estimated using micro-kjeldahl method, P by vanadomolybdophosphoric acid method and K by flame photometer.

Time of leaf collection

The data in Table 1 indicated that the nitrogen content in leaves varied from 0.74% to 1.18% in different months with different age of leaves. The youngest leaves i.e. one month old (collected in the month of May) had the highest level of nitrogen (1.18%) and the N value decreased with the increase in age of the leaves which reached at minimum level (0.74%) in the month of December. The N value again increased with the peak of 1.10% in the month of March when the leaves were 11 month old. It was noted that foliar N content did not vary so much in the month of August-September (1.11 to 1.10%) when age of the leaves was 4 to 5 month and considered as the best time of leaf sampling for estimation of foliar nitrogen. Similar trend of foliar N values in different months was noted in Bael (Ghosh, 2014), another underutilized fruit crops.

Foliar P content also varied with aging of leaves (Table 1). Highest P content (0.24%) was estimated from youngest leaves (one month old) followed by a continuous decreasing trend and lowest P (0.10%) was estimated from the oldest leaves (11 month old). The P content in leaves during August-September (4-5 month old) was found to be stable (0.19 %) and considered as the best time for P estimation.

The K content in leaves of wood apple in different months varied and followed the same pattern as in case of P (Table 1). Highest K (0.96%) was estimated from youngest leaves (one month old leaves) and lowest (0.64%) from the oldest leaves (11 month old). The foliar K value was noted stable in the month of August-September (0.85-0.84%) and considered the best time of leaf sampling for estimation of K.

Position of leaf collection

N, P, K status of leaves collected from different height of the plant has been presented in Table 2. N, P and K values in leaves has been progressively decreased from top to bottom irrespective of month of sampling. It was noted that values of N and P in leaves of top and middle portion did not vary so much as compared to leaves of bottom portion. Considering convenience, the leaves from branches of middle portion should be considered for leaf collection for estimation of N & P.

In case of values of foliar K, the difference between the top and middle position of leaves is similar when the value was compared with the middle and bottom position of leaves, irrespective of month of sampling. It was farther noted that values of K of bottom leaves is comparatively very low with the top portion. Keeping parity of work of N and P estimation, the leaves from middle position of branches of tree should also be considered for K estimation also.

Table 1. N,P and K content in leaves of wood apple at different months

Month	Leaf age	Nitrogen (% on dry weight basis)	Phosphorus (% on dry weight basis)	Potassium (% on dry weight basis)
April	Emergence of leaves started	–	–	–
May	1	1.18	0.24	0.96
June	2	1.16	0.22	0.92
July	3	1.14	0.20	0.90
August	4	1.11	0.19	0.85
September	5	1.10	0.19	0.84
October	6	0.82	0.17	0.80
November	7	0.77	0.16	0.76
December	8	0.74	0.14	0.74
January	9	1.00	0.12	0.70
February	10	1.05	0.11	0.66
March	11	1.10	0.10	0.64

Table 2. N, P and K values (%) of leaves of wood apple at different height of the plant

Month	Top Portion			Middle portion			Bottom portion		
	N	P	K	N	P	K	N	P	K
August	1.12	0.19	0.86	1.10	0.17	0.82	1.05	0.14	0.78
September	1.11	0.18	0.84	1.09	0.16	0.80	1.00	0.12	0.76

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Effect of organic manures and bio-fertilisers on growth and quality of *kharif* onion (*Allium cepa* L.) in semi-arid region

A K Meena*, R Paliwal and K K Meena

SKN College of Agriculture, Jobner, Rajasthan 303329.

*Corresponding author's email: ashokageco@gmail.com

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Onion (*Allium cepa* L.) is a bulbous biennial herb of family Alliaceae. It is commonly called as "Queen of kitchen" for its unique usage throughout the year in the form of salads, condiments or for cooking with other vegetables. The pungency in onion is due to sulphur compound "allyl propyl disulphide" in the volatile oil and the outer yellow skin colour is due to the presence of "querctin" (Nadkarni, 1954). Onion bulb is rich in minerals like phosphorus (50mg/100g), iron (0.7mg/100g), calcium (18mg/100g), carbohydrates (11.0g/100g), protein (1.2g/100g), vitamins 'C' (11mg/100g), fibers (0.6g/100g) and nicotinic acid (0.4mg/100g) (Aykroyd, 1963). The productivity of onion in India is very low (16 t ha⁻¹) in comparison to other countries. Thus there is ample scope for increasing production through fertilizers, especially that of organic manures and bio-fertilisers in light textured soil. Production of onion in *kharif* season is more important to have continuous supply of onion round the year. Organic manures stimulates the production of polysaccharides and other compounds that favours aggregation of fine soil particles, there by promoting good structure, improved tilth, aeration, moisture movement and retention (Bose *et al.*, 2001). Bio-fertiliser inoculation like *Azospirillum*, PSB helps the plants to attain better vegetative growth and increases yield by 10-30 percent (Mohondas, 1999 and Tilak and Annapurna, 1993). The present investigation was taken up to study effect of organic manures and bio-fertilisers on *kharif* onion in semi arid region.

The experiment was conducted during 2011-12 at Horticulture farm, S.K.N. College of Agriculture, Jobner (Jaipur). The soil of experimental field was alkaline loamy sand in texture at pH 8.1, poor in organic carbon (0.135 %), available N (134.70 kg/ha), P (16.85 kg/ha), K (151.65 kg/ha) and Zn (0.42 mg/kg soil). The experiment was laid out in randomized block design (RBD) with eighteen treatment combinations including six levels of organic manures (Control, FYM @ 10 t ha⁻¹, vermicompost @ 5 t

ha⁻¹, poultry manure @ 5 t ha⁻¹, FYM @ 5 t ha⁻¹ + vermicompost @ 2.5 t ha⁻¹, FYM @ 5 t ha⁻¹ + poultry manure @ 2.5 t ha⁻¹) and three bio-fertilizer treatments (without inoculation, *Azospirillum*, *Azospirillum* + PSB) with 3 replications. Randomization of the treatments was done with the help of random number table as advocated by Fisher (1950). The plot size was 2.1m X 2.4 m with 35 cm x 15 cm spacing between rows and plants. Organic manures were spread in the beds uniformly before transplanting of seedling. *Azospirillum* and PSB were applied as 100g per acre culture dissolved of water and dipping the bulb of the onion in solution for 10-20 minutes before sowing and dried in shade (Paul *et al.*, 1971). Growth attributes were calculated using standard methods and chlorophyll content was estimated by method advocated by Arnon (1949). Sulphur was estimated by Turbidimetric method (Tabatabai and Bremner, 1970), while phosphorus by digesting plant sample with Tri-acid mixture of HNO₃, H₂SO₄, HClO₄ and was estimated by "Vandomolybdo" phosphate yellow colour method (Jackson, 1973). Estimation of nitrogen was done from digested samples by colorimetric method after development of colour with Nessler's reagent (Snell and Snell, 1939) and Total soluble solids (TSS) per cent were determined using zeiss hand refractometer. The 'F-test' and critical difference (CD) calculated to test significance of difference among the treatments, wherever the results were significant.

Effect of organic manures

(i) **Growth attribute:** The increasing levels of organic manures significantly increased the plant height, number of leaves per plant, fresh weight of leaves and total chlorophyll content in leaves (Table 1). The application of FYM @ 5 t ha⁻¹ + vermicompost @ 2.5 t ha⁻¹ gave significantly highest increase in the growth attributes. Improvement in plant growth attributed might be due to the fact that organic

manures such i.e., FYM, vermicompost and poultry manure might have enhanced the soil microbial activity, which might have interned in to higher improved the physical condition of soil in respect of granulation, friability and porosity and ultimately provided a balanced nutritional environment to the soil plant nutrition system. (Kumar *et al.*, 2003 and Thanuhathan *et al.*, 1997).

(ii) Quality parameters: A significant increase in nitrogen content and TSS content of onion bulb was observed by the application of FYM @ 5 t ha⁻¹ + vermicompost @ 2.5 t ha⁻¹ (Table 1), over control. Other quality parameter viz., phosphorus content and sulphur content of onion bulb significantly increased under FYM @ 5 t ha⁻¹ + poultry manure @ 2.5 t ha⁻¹ (Table 1). This might be due to enhanced translocation of nutrient, vitamins and proteins in to the bulb, due to improved nutritional environment in the rhizosphere as well as its utilization in the plant system. This in turn helped in increased physiological functions of plants. The increased activity of nitrate reductase, which helped in synthesis of certain amino acids and protein can also be other reason (Ramesh *et al.*, 2006, Choudhary *et al.*, 2003 and Sharma *et al.*, 2009).

Effect of bio-fertilisers

(i) Growth parameters: The significant increase in plant height, number of leaves, fresh weight of bulb and total chlorophyll content of leaves were observed due to

increased inoculation of *Azospirillum* + PSB. This might be due to increase in available nitrogen and phosphorus in rhizosphere due to atmosphere nitrogen fixing by *Azospirillum* and by activity of phosphate solubilizers (Mengistu and Singh, 1999 and Barakart and Gabr, 1998). The combined inoculation of nitrogen fixer and PSB benefits the plant more than either group of organisms alone and might have added advantages in the degraded agro-ecosystem (Bareth, 1998 and Muthuramalingam *et al.*, 2001).

(ii) Quality parameters: The bulb inoculation with *Azospirillum* and *Azospirillum* + PSB significantly increased the nitrogen, phosphorus, sulphur and TSS content of onion bulb. *Azospirillum* might have fixed higher amount of nitrogen in soil and made available to the plants resulted in better uptake of N by plant. Phosphobacteria would have caused more mobilization and solubilization of insoluble P in the soil and improved the availability of phosphorus which would have caused an increase uptake of phosphorus of plants. The quality attributes improved due to higher photosynthetic rate with better source sink relationship and nutrient uptake besides excellent physiological and biochemical activities. The results are in confirmation with finding of Tanwar *et al.* (2003) and Yephtho *et al.* (2012).

Table 1. Influence of organic manures and bio-fertilisers on growth and quality attributes of *kharif* onion (*Allium cepa* L.)

Treatments	Plant height (cm)	60 Harvest DAT	No. of leaves plant ⁻¹	Fresh wt of leaves plant ⁻¹	Total chlorophyll content of leaves(mg ⁻¹)	TSS content of bulb (%)	Nitrogen content of bulb (%)	Phosphorus content of bulb (%)	Sulphur content of bulb (%)
Organic manures									
Control	28.03	48.11	9.96	52.56	0.063	9.89	0.71	0.25	0.60
FYM 10 t ha ⁻¹	32.92	51.89	10.94	56.11	0.068	10.98	0.74	0.28	0.63
Vermicompost 5 t ha ⁻¹	34.92	55.11	11.69	57.78	0.069	11.69	0.75	0.28	0.64
Poultry manure 5 t ha ⁻¹	38.24	58.22	12.43	59.83	0.071	12.34	0.77	0.32	0.67
FYM 5 t ha ⁻¹ + V.C.	43.66	63.57	13.61	63.11	0.076	13.57	0.80	0.34	0.68
2.5 t ha ⁻¹									
FYM 5 t ha ⁻¹ + P.M.	41.98	61.82	13.33	61.17	0.075	13.33	0.80	0.35	0.70
2.5 t ha ⁻¹									
SEM±	1.17	1.18	0.27	0.74	0.002	0.26	0.01	0.01	0.01
CD (p=0.05)	3.38	3.39	0.76	2.13	0.004	0.75	0.03	0.02	0.02
Bio-fertilisers									
Control	30.70	50.54	10.29	54.91	0.065	10.26	0.72	0.27	0.62
<i>Azospirillum</i>	36.82	56.92	12.27	59.12	0.073	12.22	0.76	0.30	0.65
<i>Azospirillum</i> + PSB	41.86	61.90	13.42	61.25	0.074	13.42	0.80	0.34	0.68
SEM±	0.83	0.84	0.19	0.52	0.001	0.18	0.01	0.00	0.00
CD (p=0.05)	2.39	2.40	0.54	1.51	0.003	0.53	0.02	0.01	0.01

V.C. = Vermi-compost, P.M. = Poultry Manure

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Influence of brassinolide in mitigating the adverse effect of drought on yield attributes in fenugreek (*Trigonella foenum-graecum* Linn) genotypes

M. Singh, B. L. Kakralya, P. Mahala* and V. Bhati

SKN College of Agriculture, Jobner, Rajasthan 303329

Sri Karan Narendra Agriculture University, Jobner, Rajasthan-303329

Swami Keswanand Rajasthan Agricultural University, Bikaner

*Corresponding author e-mail: pmhorti@gmail.com.

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Fenugreek (*Trigonella foenum-graecum* L.) is grown as vegetable, grain as well as for fodder purpose in India. Fenugreek seeds substantially contain important steroid saponin called "Diosgenin", whose content in seed varies from 0.62-2.20 per cent which is used in synthesis of sex hormones and oral contraceptives. Water stress in India is a serious problem for crop production, as approximately 70 per cent of cultivated land is rainfed. Brassinosteroids application under abiotic stress influence hydrolysis of polysaccharides, resulting in increase of soluble sugars and confer resistance against environmental stresses in crop plants and also enhances the crop productivity (Rao *et al.*, 2002 and Vidya Vardhini *et al.*, 2006). A considerable amount of research has been done on cereal crops under stress condition. However, adequate work has not been done on the effects of water stress on or seed spices crops. Keeping this in view, the experiment was undertaken to study the role of brassinolide in mitigating the adverse effect of drought on yield attributes and varietal response of fenugreek genotypes.

A pot experiment was carried out in the cage house, Department of Plant Physiology, S.K.N. College of Agriculture, Jobner (Rajasthan). One hundred twenty ceramic pots were filled with about 10 kg of soil with well-mixed FYM in each pot. The experiment was laid the four fenugreek varieties RMt-1, RMt-361, RMt-305 and Hissar Sonali with grown under non-stress and water stress conditions. Brassinolides (BR) of different concentrations (control, 0.25 ppm, 0.50 ppm, 0.75 and 1.00 ppm) were sprayed prior to stress application, at pre flowering stage and next at 10 days after first spray, under both the conditions. The observations were recorded on number of seeds per pod, number of pods per plant, seed yield per plant, seed index, biological yield and harvest index as per

standard methods. The data collected and analyzed statistically using completely randomized design (Panse and Sukhatme, 1970).

All the yield attributes have significantly increased with increasing brassinolide concentration with the highest values was obtained at 1.00 ppm concentration spray and minimum at control under both stress and non-stress conditions. Highest seed yield was recorded with 1.00 ppm with variety RMt-305 and lowest with control with RMt-361. Similar results have also been reported by Quasim *et al.* (2008). Water stress induced reduction in growth parameters was also reflected in number of seeds per pod, number of pods per plant and seed index (Hamid *et al.*, 1990). Brassinolide application caused significant increase yield parameters, under both irrigated and stressed plants (Takemastu *et al.*, 1983).

Water stress caused decrease in biological yield and harvest index as compared to non-stress condition. Biological yield increased with increase in brassinolide application. In case of harvest index, the results showed significant variations. Thus it can be inferred that the fenugreek varieties differed significantly for water stress tolerance. It is suggested that tolerance of RMt-305 to water stress might be due to better management of physiological processes at cellular level. The effect of these parameters and brassinolide were clearly reflected in yield attributes of fenugreek varieties.

On the basis of the present investigation it may be concluded that cultivar RMt-305 performed better in comparison to all other genotypes with respect to all the yield parameters. Application of brassinolide significantly increased all parameters and 1.00 ppm was found most effective concentration under control and water stress conditions.

Table 1. Influence of brassinolide in mitigating the adverse effect of drought on yield attributes in fenugreek genotypes

Treatments	Number of seeds per pod	Number of pods per plant	Seed yield per plant (g)	Seed index	Biological yield (g)	Harvest index (%)
Variety						
RMt-1	14.05	38.22	5.72	1.03	19.49	28.86
RMt-361	11.29	36.10	3.15	0.70	13.29	22.29
RMt-305	14.67	40.06	7.64	1.25	24.01	31.29
Hissar Sonali	12.61	37.46	4.32	0.87	16.73	24.78
S.E.m.±	0.19	0.29	0.10	0.01	0.18	0.51
C.D. (P=0.05)	0.53	0.83	0.29	0.02	0.50	1.44
Stress						
Non stress	14.15	42.88	6.72	1.07	21.04	31.27
Water stress	12.16	33.04	3.70	0.85	15.72	22.34
S.E.m.±	0.13	0.21	0.07	0.01	0.13	0.36
C.D. (P=0.05)	0.38	0.58	0.21	0.02	0.35	1.02
Brassinolide (ppm)						
0.0	11.64	33.38	3.63	0.88	14.51	23.78
0.25	12.64	35.45	4.38	0.92	16.19	25.66
0.50	12.97	37.49	4.97	0.96	17.36	27.29
0.75	13.48	40.31	5.79	1.00	20.47	27.21
1.00	15.05	43.18	7.27	1.05	23.38	30.08
S.E.m.±	0.21	0.33	0.12	0.01	0.20	0.57
C.D. (P=0.05)	0.59	0.92	0.33	0.03	0.56	1.61

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