Review Article

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The shot hole borer (Ambrosia beetle): Deciphering component in wilt complex as an emerging issue in pomegranate-A review

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ABSTRACT

Ambrosia *i.e.* shot hole borer beetles are beetles of the weevil subfamilies Scolytinae and Platypodinae (Coleoptera, Curculionidae), which live in nutritional symbiosis with ambrosia fungi. The beetles excavate tunnels in preferably wilted dead, stressed plants and little bits in healthy trees in which they cultivate fungal gardensas their sole source of nutrition. The shot hole borer, *Xyleborus fornicatus* severely affected pomegranate as this pest occurs sporadically in Ahmednagar. Life cycle from egg emergence to adult life of this pest was completed in 34 days with 13:1 female to male ratio. The symbiotic fungus *Fusarium euwallaceae* is associated with *Euwallaceae fornicatus* causing branch dieback once introduced. Beetle play key role in the mechanical transmission of wilt pathogens. Because of haplodiploidy nature there is no need to find mates, brother-sister mating increases the chances of colonization and therefore, one or a few individuals are sufficient to establish a new population. As deciphering component, the wilt incidence reported from 0 to 46.3 per cent of survey report in Bagalkote followed by Belgavi in Karnataka and stated that the infestation of shot hole borer alone was not noticed. Furthermore, association of shot hole borer and nematode results in higher per cent disease incidence. Maintaining healthy trees by reducing physiological stress is the first recommendation for long term control. If growers maintain optimal condition the ubiquitous amborsia beetle will be in consequential. Pasting of geru with and drenching of emamectin benzoate at 2 g + propiconazole 1 ml per litre water in infested plant will be effective remedy for the management of pest with symbiotic fungal inoculum.

Introduction

Shot Hole Borer, *Euwallacea fornicatus* has a complex taxonomic history. *E. fornicatus* was originally described as *Xyleborus fornicatus* by Eichhoff in 1868 from an unknown host plant and locality (Danthanarayana, 1968). Outside Ceylon this species is known to occur only in Java, Malaya; Formosa and India. (Austin, 1956). It was referred to as *E. fornicatus* species complex. Without making any attempt to

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resolve the taxonomy, they were referred to as vernacular names, the polyphagous shot hole borer (PSHB), kuroshio shot hole borer (KSHB) and tea shot hole borer (TSHB). *Euwallacea* is a genus of over 40 species within the largest tribe of scolytine beetles the Xyleborini, which contains nearly 1200 described species (Hulcr*et al.,* 2015).

Ambrosia beetles are beetles of the weevil subfamilies Scolytinae and Platypodinae (Coleoptera, Curculionidae), which live in nutritional symbiosis with ambrosia fungi. The beetles excavate tunnels in wilted, dead, stressed and healthy trees in which they cultivate fungal gardens, their sole source of nutrition. In tunnel releases spores of its fungal symbiont. The fungus penetrates the plant's xylem tissue and extracts nutrients (Kasson *et al.,* 2016). Recent reports, in California have shown that invading beetle species might act as pests as they can carry plant pathogens within their symbionts (Hulcr and Dunn, 2011). This is in the case of beetles in the *Euwallacea fornicatus* (Eichhoff) species complex, which are native to Southeast Asia (Gomez *et al.*, 2018). Ecological and biological features, such as fungus-farming, haplodiploidy reproduction and a wide host range, make the Xyleborini one of the most successful colonizers (Kirkendall *et al.*, 2015). Most of the ambrosia beetle evolved from bark beetles bores into wood tissue and feed on it. However, ambrosia beetle not consume any wood tissue (Johnson *et al.*, 2018). Despite, the common narrative in the scientific literature, most ambrosia fungi are poor wood degraders (Licht and Huang *et al.*, 2019). About 5,812 species under two subfamilies 25 tribes and 225 genera are known from the world (Wood and Bright, 1992). Out of these, about 270 species, 65 genera, 18 tribes and two subfamilies are so far recorded from India. The fungus commonly associated with the ambrosia beetle *Xyleborus fornicatus* Eich., is described as new and named as *Monacrosporium ambrosium* (Gadd and loos, 1947) in Srilanka while in California and Israel it is *Fusarium euwallacea* (Freeman *et al*., 2013)

Economic importance of shot hole borer (Ambrosia beetle)

In Southern India and Sri Lanka, *E. fornicatus* is an important pest of tea crop (CABI, 2015; Walgama, 2012), but the information about quantified loss cause by this pest is little precise. In Sri Lanka, this pest covers more than 75% of the total tea growing extent (Walgama, 2014), characteristics such as concealed habit, wide distribution and wide host preference make pest control difficult (Walgama, 2014).This pest has recently become a serious pest of pomegranate in Southern India. In California, the Shot hole borer also threatens avocado tree. The losses could be high, as California is the main producer of avocado in the USA, and it is estimated at $350 million per year (Ploetz *et al.,* 2013).Currently, this pest having largest economic impact on avocado in Israel cover approximately 7,000 ha.

Life history: The life history was recorded from the commencement of boring a gallery to egg-laying (8 days); egg period (7 days); larval stage (15 days); pupal stage (7 days). Therefore, the life cycle from egg to egg was found to about 40 days. The total life cycle including longevity was about 42 days. Distinct sexual dimorphism was observed among adult beetles, and usually females were more in number than males with a sex ratio of 13 female: 1 male per tube (Jayanthi Kamala *et al.,* 2020).

Pomegranate shot hole borer: The spread of *E. fornicatus* to various regions around the world and the damage that has followed appear to suggest that this species is much more invasive and damaging than the remaining ones (Smith *et al.*, 2019). While, some of the greatest damage in natural systems appear to be associated with tree stress including flooding and pollution (Boland and Woodward, 2019).

Host: The shot hole *borer, X. fornicates* infestation on pomegranate in Maharashtra was first r eported b y Mote f rom Ahmednagar district in the year 1991 and recorded new host for this pest from this area (Mote,1991). Further, *X. perforan* was observed as new record on pomegranate in Karnata-ka (Jagginavar and Naik, 2001) has been recorded as a new host of shot hole borer, *Xyleborus perforans* (Wollastan) in Karnataka (Naik and Nandihalli, 1996). Kumar *et al.* (2011) recorded new host plant for shot hole borer on *Persea bom-bycina* Kost (Lauraceae) from Jorhat of Assam in India and causes appreciable damage during year 2010. *E. fornicatus* is reported as a pest of tea in several places in south east Asia (CABI, 1973 and James, 2007).

Host selection: Even though ambrosia beetle often said to colonize stressed, dead or living trees. Only very few am-brosia beetle species and their fungal associates such as the black twig borer, *Xylosandrus compactus* are able to colonize healthy living trees, attack only the twigs of healthy trees causing the end of the twig to die. However, a few species including *E. fornicatus*, *E. kuroshio*, and *E. perbrevis*, colonize healthy trees and cause damage through mass accumulation (Hulcr and Stelinski, 2017). Owens *et al.* (2018) reported that the adult females usually disperse during the day, attacking hosts in a range of tens of meters (hundreds of feet). The SHB activities were observed in the wilt-infected pomegranate plants with symptoms of branch drying and leaf shedding ranging from 15.0 % to 100.0% (Jayanthi Kamala *et al.*, 2020).

Factors influencing the shot hole borer attack: In nutrient enrichment increases their susceptibility to shot hole borer attack. After attacked by the KSHB, the trunks and branches of these nutrient enriched trees provide an environment con-ductive to the fast growth of the symbiotic fungi upon which

KSHB feeds (Boland and Woodward 2019). Nutrient enrichment influence wood characteristics, and heavy fertilization and irrigation leads to fast growth, low density wood and high moisture content in several species of trees (Hacke *et al.*, 2010 and West, 2014). The standard medium for growing ambrosia beetles and their symbiotic fungi in the laboratory is water based and rich in nutrients. The growth rates of the fungi and larvae of ambrosia beetles are positively correlated with the moisture content of host plant. (Jayanthi Kamala *et al.*, 2020).

Plant part affected and their symptoms: The severity of this pest was observed on main trunks and branches of pomegranate in Maharashtra (Mote and Tambe, 1991). Generally, shot hole borer occurs in maximum numbers at the base of the trunk in 0 to 30 cm, trunk height with more incidence on older plants than younger plants (Tambe and Mote, 1997). The correlation between age of the plant and total number of shot holes indicated a significantly positive relationship (Jagginavar and Naik, 2004). Jagginavar and Naik, 2001 observed the more activity at ground level (0 to 30 cm) than on the higher trunk level (31 to 90 cm).

Spread: From an infested tree adults migrate, within a month, to the nearest healthy trees and further infestation starts. The rate of spread of infestation at this time will be rapid and a whole orchard can show symptoms within 3 to 6 months. From one orchard, the infestation can spread to neighbouring orchards easily (Verghese and Jayanthi, 2001).

Potential impacts and challenges for its management

Ambrosia beetle exposure to surface-applied insecticides is minimal after internal trunk galleries are formed, so effective management requires insecticide treatments to be applied near the time of infestation or to have residual activity on the bark (Matthew *et al.,* 2020). With regard to the fungus, according to Batra 1985, since mutualistic insect pests in general will not survive or reproduce in nature without their mycosymbionts, it is evident that controlling the fungus may also control the insect. Several fungicides such as carbenzamin, prochloraz and tebuconazole, have been evaluated on avocado crop. In laboratory experiments, all of them seemed to inhibit fungus growth, however fungicides were not effective in field trials (Freeman *et al.,* 2012 and Mendel *et al.,* 2012).

Wilt disease component

Studies revealed that wilt disease shows symptoms caused by many contributing biotic and abiotic factors. Several biotic factors like fungal pathogens (viz. *Ceratocystis fimbriata*, *Fusarium spp*., *Macrophomina phaseolina*, *Phytophthora spp*., *Rhizoctonia bataticola*, *Rosellenia necatrix*, *Verticillium dahliae*), insects (scolytid beetle, *Xyleborus perforans* (Wollaston)) and nematodes (root-knot nematode, *Meloidogyne incognita*) were found to play a crucial role in disease progression (Darekar *et al.*, 1990). Similar observations were also recorded by (Shreeshail *et al.*, 2016) that *Ceratocystis fimbriata*, *Meloidogyne incognita* and shot hole borer are responsible for causing wilt complex with a high frequency of earlier two pathogens from soil and root sample.

The role of Island pinhole borer, *Xyleborus perforans* (Wollaston) popularly known as pomegranate shot hole borer (SHB), in causing pomegranate wilt is well established (Sharma *et al.*, 2010; Somasekhara and Wali, 2000). In Japan, the known causal agent of wilt disease on fig trees (*Ficus carica* L.) is *Ceratocystis ficicola* (Kajitani and Masuya., 2011). Fig wilt disease (FWD) has been found to be caused by the infestation of ambrosia beetle, *Euwallacea interjectus* (Blandford) (Kajii*et al.*, 2013).

Preventative and curative management

Beetles are not the cause of the tree stress but a sign of other stressors. Focusing management on the beetle is likely going to be less effective than ameliorating the underlying causes. If growers maintain healthy trees and optimal growing conditions, the ubiquitous ambrosia beetles will be mostly inconsequential (Hulcr and Skelton, 2023). The association of beetles with symbiotic and auxiliary fungi presents another challenge because the symbionts of beetles are known to be pathogenic on their hosts (Lynch *et al.,* 2016; Mendel *et al*., 2012 and Na *et al*., 2018). Mayorquin *et al*. (2018) highlighted the possibility for two levels of management: one to directly manage vector populations and a second level which aims to manage the fungal populations established by shot hole borer once a host has been invaded. One of the major challenges appears to be the effective introduction of the chemicals into the vascular system, particularly in infested trees where the distribution of the chemical may be disrupted by tunnelling and fungal colonization (Mayorquin *et al.*, 2018). Maintaining plant health by reducing physiological stress is the first recommendation for long-term control (Gugliuzzo *et al*., 2021).

Control has been a difficult task as a result of concealed habit virtually protected from parasites and predators. Biological control using entomopathogenic fungus, *Beauvaria bassiana*is being viewed as an environmentally friendly alternative to chemical control in the light of growing concern on the usage of pesticides. Laboratory studies have shown that strains of this fungus are highly pathogenic to shot hole borer imparting more than 90 % mortality (Walgama *et al.,* 2006). Anonymous (1993) recommended preventing for control shot hole borer (*Xyleborus* spp.) which is associated with wilt disease, 10 litres preparation (paste) containing red soil (4

kg) + chlorpyriphos 20 EC (20 ml) + copper oxychloride 50 WP (25 g) needs to be applied on stem surface from plant base up to 2 ft. from second year onwards. Pasting should be done twice a year; once soon after the harvest and once at defoliation, before crop regulation. Mayorquin *et al.* (2018) in California conducted study on sycamore (*Platanus racemosa*) for chemical management of invasive shot hole borer and Fusarium dieback which revealed that, the fungicides revealed that pyraclostrobin, trifloxystrobin and azoxystrobin generally have lower effective concentration that reduces 50 % of mycelial growth (EC_{50}) values across all fungal symbionts of PSHB and KSHB. A one year field study showed that two insecticides, emamectin benzoate alone and in combination with propiconazole, and bifenthrin, could significantly reduce SHB attacks. Two injected fungicides (tebuconazole and a combination of carbendazim and debacarb) and one spray fungicide (metconazole) could also significantly reduce SHB attacks. In California Grosman *et al.* (2019) recorded that, the preventive treatments with Emamectin benzoate + propiconazole was the most effective treatment for reducing polyphagous shot hole borer attack levels, sap flow/bleeding from attack holes, proportion of beetle emergence and tree mortality. Emamectin Benzoate alone appears to be more durable lasting for one year when beetle pressure is high or as many as more than two years when pressure is relatively light. Emamectin benzoate + propiconazole had the greatest durability; being able to suppress beetle attacks for two years under high beetle pressure.

Jones and Paine (2018) noted that bifenthrin was the most effective insecticide for reducing beetle attacks and gallery formation in castor bean branches in laboratory with cut branches. Byrne *et al.,* (2020) conducted several field trials of trunk injection of systemic insecticide emamectin benzoate in avocado trees. Emamectin benzoate established quickly within trees at the threshold concentration in the areas most vulnerable to attack and colonization by KSHB. Injection of the insecticide in a more dilute form promoted both faster uptake and more rapid establishment of effective concentrations than the undiluted form.Rudinsky (1966) reported that a shortage of suitable breeding material is a decisive factor in limiting *Xyloborum fornicatus* numbers. Speyer (1917b) suggested that removing castor oil plants, which are an alternative host plant for *Xyleborus fornicatus*. The first attempt at biological control was made in 1909 (Austin 1956) with a predacious beetle, *Clerus fornicarious* Fischer, from Scotland, but the beetle larvae were too large to live in *Xyloborum fornicatus* galleries. The chalcid *Perniphora robusta*, a principal parasite of bark beetles in Europe was imported in 1970, whereas another chalcid, *Tricholasxylpcleptis* and a braconid, *Heterospilusater* were imported and released in the tea plantations in mid country but with no success as the parasites failed to establish (Danthanarayana, 1970; Sivapalan, 1974 and Thirugnanasundaran, 1989). Danthanarayana (1966) tested a strain of *B. bassiana* fungus showed promise in laboratory experiments, but attempts at control under field conditions proved futile.

Conclusion

Shot hole borer beetles belong to the weevil subfamily Scolytinae (Coleoptera, Curculionidae) and engage in a nutritional symbiosis with ambrosia fungi. These beetles create tunnels in wilted, dead, or stressed plants, cultivating fungal gardens that serve as their primary source of nutrition. To achieve long-term control in pomegranate cultivation, the first recommendation is to maintain plant health by minimizing physiological stress. Preventive measures for managing the shot hole borer (*Xyleborus spp.*), which is associated with wilt disease, include applying a trunk paste made from 10 litre preparation containing 4 kg of red soil, 20 ml of chlorpyrifos 20 EC, and 25 g of copper oxychloride 50 WP. This mixture should be applied to the stem surface from the base of the plant up to 2 feet, starting from the second year before crop regulation. Alternatively, drenching infested plants with a solution of 2 g of emamectin benzoate and 1 ml of propiconazole per litre of water can be an effective remedy for managing this pest along with its symbiotic fungal inoculum.

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Research Article

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Effect of NPK and sulphur on yield of cauliflower (*Brassica oleracea* var. *botrytis* L.)

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ABSTRACT

A field experiment was conducted at the Horticulture Farm of the Rajasthan Agricultural Research Institute in Durgapura, Jaipur, during the Rabi season of 2019-20. The study included four levels of NPK (0%, 60%, 100%, and 120% of the recommended dose) and four doses of sulphur (0, 20, 40, and 50 kg/ha), resulting in a total of 16 treatment combinations. These treatments were tested using a randomized block design with three replications. The results indicated that the application of 100% of the recommended dose of NPK, along with sulphur @ 40 kg/ha, was the most effective treatment combination for the cauliflower crop. This combination resulted in an average curd weight of 431.81 g, a total curd yield per plot of 122.68 kg, and a total curd yield of 213.24 q/ha.

Introduction

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is one of the most popular vegetable crops among cole crops and belongs to the Cruciferae family. It is cultivated year-round for its white and tender curds. In India, two main groups of cauliflower are commonly grown: Indian or tropical types, which originated in India, and annual temperate or European types, also known as 'Erfurt' or snowball types. Indian types typically form curds at temperatures between 20 to 26°C, while temperate types require cooler conditions of 10 to 16°C for curd formation. The Indian varieties are notably resistant to waterlogging and heat. Cauliflower is versatile and can be prepared in various ways, including frying, drying, making soups, and pickling. In Rajasthan, cauliflower is extensively cultivated in districts such as Ajmer, Alwar, Tonk, Sikar, Bundi, Bharatpur, Nagaur, Rajsamand, Ganganagar,

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Jaipur, and Jodhpur. The state has approximately 10.2 thousand hectares dedicated to cauliflower cultivation, yielding around 5.17 thousand tons. In India as a whole, it is grown over an area of about 0.43 million hectares, with an annual production of approximately 8.2 million tons and a productivity rate of about 19.25 tons per hectare (Anonymous, 2016).

Nitrogen plays a key role in promoting vigorous vegetative growth and aids in the development of large, compact cauliflower curds. Phosphorus, a vital component of nucleic acids, phytin, and phospholipids, is crucial during the early stages of plant growth, as it helps establish the primordia for reproductive parts in cauliflower. Potassium contributes to increased plant vigor and disease resistance by regulating water movement within plant cells and maintaining the balance between anabolism, respiration, and transpiration. Sulphur plays a critical role in the biosynthesis of amino acids like cysteine, cystine, and methionine, which are key components of proteins. Additionally, sulphur is involved in the synthesis of coenzyme-A, the formation of chlorophyll, and the functioning of the nitrogenase enzyme. It is also present in growth regulators like thiamine and biotin, and in glutathione, which is important for oxidation-reduction reactions (Kanwar, 1976). Sulphur involved in numerous metabolic and enzymatic processes within plants (Goswami, 1988). With the reduction of sulphur dioxide (SO_2) emissions to less than 10 kg per hectare, sulphur deficiency in plants has become more prevalent, as up to 30% of sulphur can be absorbed from SO_2 in the air. The sulphur cycle, similar to nitrogen, involves soil oxidation and reduction within plants, but sulphur from organic compounds can be re-oxidized to sulfate (SO_4-S) in plants (Vanek *et al.*, 2001).

Therefore, considering the crucial role of macronutrients (NPK) and sulphur in the growth and development of cole crops, this study is undertaken to determine the optimum doses of nitrogen, phosphorus, potassium, and sulphur for cauliflower cultivation. The aim is to enhance plant health, improve curd quality, and ensure better nutrient management for optimal yield.

Material and Methods

The field experiment aimed at studying the response of NPK and sulfur on the yield of cauliflower was conducted at the Research Farm of the Rajasthan Agricultural Research Institute in Durgapura, Jaipur, during the Rabi season (October to January) of 2019-20. The experiment was comprised of 16 treatment combinations laid out in Randomized Block Design (RBD) with four levels of NPK (0, 60, 100 and 120 % RD of NPK) and sulphur (0, 20, 40 and 60 kg/ha). The recommended dose of NPK for cauliflower cultivation is 120 kg, 80 kg and 80 kg per ha, respectively. Full dose of P_2O_5, K_2O and half dose of N in various treatments were applied manually as the basal dose at the time of transplanting. The remaining dose of nitrogen was given as top dressing in two split doses at 30 and 45 days after transplanting. Sulphur was applied as per treatment through agriculture grade elemental Sulphur and was broadcasted uniformly before transplanting and incorporated in the soil. Seeds of cauliflower cv. Pusa KT1 obtained from National Seed Corporation and treated with 0.02 per cent Thiram to save the seedlings from damping off disease. A thin layer of powered leaf mould was used to cover the seeds. The crop was provided with optimum irrigation. The seedlings were ready for transplanting in 4-5 weeks. Five weeks old seedlings were transplanted on 5th October, 2019, when average height of seedlings was about 10-12 cm. The distance between row to row and plant to plant was kept at 45 x 45 cm. Thus, 16 plants were accommodated in each plot. The transplanting was done in evening hours followed by light irrigation.

Results and Discussion

Effect of NPKs on growth attributes

The data revealed that different NPK levels had a significant effect on plant height and the number of leaves per plant at various growth stages (Table 1). The mean maximum plant height at 30, 60 days after transplanting (DAT), and at harvest was 30.8 cm, 46.5 cm, and 58.2 cm, respectively. Similarly, the corresponding number of leaves per plant at 30, 60 DAT, and at harvest was 13, 18, and 25, respectively in response to 120 per cent recommended dose of NPK (F_2). This was found to be significantly higher over F_0 (Control) and F_1 (60 per cent RD of NPK) but statistically to at par to F_2 treatment. The data presented in the same table indicated that the days taken for curd initiation were not significantly affected by the different fertility levels. Leaf area and chlorophyll content of cauliflower were significantly influenced by different fertility levels. The mean maximum leaf area and chlorophyll content were 868.3 cm^2 and 1.40 mg/g recorded under F_3 (120 per cent recommended dose of NPK), which was found to be significantly higher over F_0 and F_1 but it was statistically at par with F_2. These results are closely aligned with the findings of Baghel and Singh (1995), Patil *et al.* (2003), and Abd el-All and El-Shabrawy (2013), who have reported similar outcomes in their studies.

Effect of NPKs on yield attributes

The mean maximum average weight of curd (371.65 g) and volume of curd (264.66 CC) was observed in F_3 *i.e.* 120 per

cent recommended dose of NPK, which was found to be significantly higher over F_0 and F_1 but it was statistically at par with F_2 *i.e.* 100 per cent recommended dose of NPK (Table 2). Whereas, minimum volume of curd (150.76 CC) was recorded under F_0 treatment. In case of yield data reveals that total yield of curd per plot and per ha was significantly influenced by various fertility levels. The maximum yield of curd per plot (5.95 kg) and total curd yield/ ha (183.5 q/ha) was recorded under 120 per cent recommended dose of NPK (F_3) followed F_2 and F_1. While minimum curd yield /plot (3.42 kg) and yield/ (105.60 q) was recorded under control. The maximum yield of curd/ plot and yield/ ha under the treatment F_3 was found significantly more over to F_0 and F_1 but it was statistically at par with F_2 treatment.

The application of 100 per cent recommended dose of NPK significantly increased the average weight of curd (g), curd yield per plot (kg), curd yield per ha and volume of curd (CC). However, 100 per cent recommended dose of NPK (F_2) was statistically at par to 120 per cent recommended dose of NPK (F_3) in all the above characters. This might be due to the fact that increased NPK levels, helped in the expansion of leaf area and chlorophyll content which together might have accelerated the photosynthetic rates and in turn increased the supply of carbohydrates to plants. The application of 100 per cent recommended dose of NPK favoured the metabolic and auxin activities in plant and ultimately resulted in increasing curds weight, volume of curd finally the total yield. However, potassium does not increase the yield of plant but indirectly supported to yield. These results are also in close conformity with the finding of Batel *et al.* (1997), Everaarst and Boou (2000), Yaldas *et al.* (2008) and Abd el-All and EL-Shabrawy (2013).

Effect of sulphur on growth attributes

The application of sulphur @ 40 kg/ha have significantly increased the plant height and number of leaves per plant as compared to 20 kg sulphur per ha and control (Table 1). The maximum plant height of 30.8, 46.1 and 57.5 cm at 30, 60 DAT and at harvest and number of leaves per plant of 12, 18 and 25 cm at 30, 60 DAT and at harvest, respectively were recorded with 60 kg S /ha. However, 60 kg/ha was found statistically at par to it. The interaction effect of fertility levels and sulphur dose on plant height, number of leaves per plant and days taken to curd initiation was found to be non-significant. Application of different sulphur doses had significant effect on leaf area and chlorophyll content of leaves. The maximum leaf area (871.00 cm^2) and maximum value of chlorophyll (1.46 mg/g) content was recorded with 60 kg S/ ha which was statistically at par with 40 kg S/ha. The mean minimum leaf area and chlorophyll content of leaves was recorded in S_0 (control). The mean increase in leaf area and chlorophyll content of leaves under S_2 treatment was found to be 24.07, 8.78 and 31.43 and 10.40 per cent over S_0 and S_1, respectively. The increase in vegetative growth of cauliflower due to sulphur fertilization is consistent with the findings of Yadav and Paliwal (1990), Biswas *et al.* (1995), Dhar *et al.* (1999), Bhagavatagoudra and Rokhade (2001), Meena (2004), and Mahmud *et al.* (2005).

Effect of sulphur on yield attributes

Data presented in Table 2 revealed that the application of 40 kg S/ha significantly increased average weight of curd (g), total curd yield per plot (kg), total curd yield per ha (q) and volume of curd (CC) as compared to control and 20 kg sulphur but remained statistically at par with 60 kg sulphur per ha. The highest average weight of curd (372.08 g) and volume of curd (266.3 CC) was recorded with 60 kg/ha which was statistically at par with 40 kg/ha whereas minimum was recorded under control. The maximum curd yield per plot (5.95 kg) and per ha (105.77 q/ha) was recorded with 60 kg S/ha, which was statistically at par with 40 kg S/ha. These finding corroborates with the research of Hossan and Olsen (1966), Hara *et al.* (1981), Bijania and Dixit (1996), Dhar *et al.* (1999), Bhagavatagoudra and Rokhade (2001), Jamre *et al.* (2010) and Talukder *et al.* (2013).

Interactive effect (F x S)

The treatment combination F_3S_3 resulted in the maximum average curd weight of 449.84 g, curd yield per plot of 7.20 kg, and curd yield per hectare of 222.14 q/ha, which were significantly superior to both the control and other treatment combinations (Table 3). However, F_3S_3, was statistically comparable to F_2S_2, F_3S_2, and F_2S_3. In contrast, the minimum curd weight of 148.98 g, curd yield per plot of 2.38 kg, and curd yield per hectare of 73.57 q/ha were recorded with the F_0S_0 treatment combination (control). The results are in agreement with the findings of Jamre *et al.* (2010) and Abd el-All and El-Shabrawy (2013).

Conclusion

Based on the findings of the experiment, it can be concluded that the treatment combination F_3S_2, which consists of 100% of the recommended dose of NPK and sulphur at 40 kg/ha, resulted in an average curd weight of 431.81 g, a total curd yield per plot of 122.68 kg, and a total curd yield of 213.24 q/ha.

Table 1. Effect of NPK and sulphur on growth attributes of cauliflower

Treatments	Plant height (cm)			No. of leaves per plant			Days taken to curd initiation	Leaf area (cm^2)	Chlorophyll content (mg/g)
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest			
Fertility levels									
Control (F_0)	25.6	39.7	47.8	9	15	20	65	695.9	1.07
60 per cent RD of NPK (F_1)	27.7	42.9	53.1	10	17	21	61	786.3	1.24
100 per cent RD of NPK (F_2)	30.6	45.1	57.0	12	17	24	56	853.9	1.35
120 per cent RD of NPK (F_3)	30.8	46.5	58.2	13	18	25	54	868.3	1.40
SEm±	0.86	0.76	1.09	0.29	0.29	0.54	2.40	14.00	0.04
CD at 5%	2.48	2.19	3.14	0.84	0.84	1.57	NS	40.44	0.11
Sulphur levels (kg/ha)									
Control (S_0)	25.1	39.8	48.7	9	15	19	64	690	1.03
Sulphur 20 kg ha^{-1} (S_1)	28.2	43.1	53.0	11	17	22	60	787	1.23
Sulphur 40 kg ha^{-1} (S_2)	30.7	45.3	56.9	12	17	24	56	856.2	1.36
Sulphur 60 kg ha^{-1} (S_3)	30.8	46.1	57.5	13	18	25	57	871	1.44
SEm±	0.86	0.76	1.09	0.29	0.29	0.54	2.40	14.00	0.04
CD at 5%	2.48	2.19	3.14	0.84	0.84	1.57	NS	40.44	0.10

Table 2. Effect of NPK and sulphur on yield attributes of cauliflower

Treatments	Average weight of curd (g)	Volume of curd (cc)	Curd yield (kg/plot)	Curd yield (q/ha)
Fertility levels				
Control (F_0)	213.80	150.78	3.42	105.60
60 per cent RD of NPK (F_1)	286.62	211.37	4.59	141.56
100 per cent RD of NPK (F_2)	358.70	247.36	5.74	177.15
120 per cent RD of NPK (F_3)	371.65	264.66	5.95	183.55
SEm±	5.62	6.98	0.09	2.74
CD at 5%	16.24	20.16	0.26	7.92
Sulphur levels (kg/ha)				
Control (S_0)	214.15	147.13	3.43	105.77
Sulphur 20 kg ha^{-1} (S_1)	286.25	212.53	4.58	141.37
Sulphur 40 kg ha^{-1} (S_2)	358.36	248.19	5.73	176.98
Sulphur 60 kg ha^{-1} (S_3)	372.02	266.32	5.95	183.73
SEm±	5.61	6.98	0.09	2.74
CD at 5%	16.22	20.16	0.26	7.92

Table 3. Interactive effect of NPK and sulphur on yield attributes of cauliflower

Treatments	Fertility levels											
	Average weight of curd (g)				Curd yield (kg/plot)				Curd yield (q ha^{-1})			
Sulphur levels	F_0	F_1	F_2	F_3	F_0	F_1	F_2	F_3	F_0	F_1	F_2	F_3
Control (S_0)	148.98	199.71	249.07	258.96	2.38	3.20	3.99	4.14	73.57	98.62	123.00	127.88
Sulphur 20 kg ha^{-1} (S_1)	199.13	266.94	332.91	346.13	3.19	4.27	5.33	5.54	98.34	131.82	164.40	170.93
Sulphur 40 kg ha^{-1} (S_2)	248.42	333.02	420.31	431.81	3.97	5.33	6.72	6.91	122.68	164.45	207.56	213.24
Sulphur 60 kg ha^{-1} (S_3)	258.79	346.92	432.65	449.84	4.14	5.55	6.92	7.20	127.80	171.32	213.65	222.14
SEm±	11.25				0.18				5.48			
CD (0.05)	32.49				0.52				15.83			

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Screening of Custard apple (*Annona squamosa L.*) genotypes for fruit rot resistance

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ABSTRACT

Custard apple (*Annona squamosa* L.) is a hardy dryland horticultural crop with high export potential and significant economic benefits. However, fruit rot, caused by *Colletotrichum gloeosporioides* Penz, is one of the major diseases that can lead to substantial losses in yield. The study revealed that all 30 genotypes were infected by the disease. The Attached Fruit Culture (AFC) method showed that a higher number of genotypes exhibited a highly susceptible reaction when inoculated using the Mycelial Bit Inoculation Method (MBIM) compared to the Micro Droplet Inoculation Technique (MDIT). In the MBIM method, the genotypes Vrudheshwar-3, Verul-2, Karkhel, Vrudheshwar-4, Vrudheshwar-2, Telgaon Local, Humnabad Local, and Dhanagarawadi-3 exhibited moderate resistance. In the MDIT method, Vrudheshwar-3, Verul-2, and Karkhel showed resistance to the disease. Additionally, under natural field conditions, Vrudheshwar-3, Verul-2, Karkhel, Humnabad Local, Dhanagarwadi-3, and Vrudheshwar-4 were recorded as resistant to fruit rot disease.

Introduction

Custard apple (*Annona squamosa* L.) is a significant dryland fruit crop in India, originating from the tropical regions of the Americas and belonging to the Annonaceae family. The Portuguese introduced custard apple to India in the 16th century, and it thrived in the Deccan Plateau's subtropical climate. The Southern Tropical Plateau of India has a long history of cultivating custard apples (Hayes, 1953; Venkataratnam and Satyanarayanaswamy, 1958; Venkataratnam, 1959). Despite its adaptability, both biotic and abiotic factors, particularly diseases caused by various pathogens, are major contributors to reduced yields.

Custard apple is affected by several diseases, including fruit rot caused by *Fusarium*, *Phytophthora*, *Phoma*, *Pestalotia*, among others, Diplodia rot caused by *Botryodiplodia theobromae*, black canker caused by *Phomopsis annonacearum*, leaf spot caused by *Alternaria* spp., *Cercospora* leaf spot (*Cercospora annonae*), and anthracnose/fruit rot caused by

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Colletotrichum gloeosporioides (Mukarji and Bhasin, 1986). Among these, the most serious disease is fruit rot caused by *Colletotrichum gloeosporioides*, which poses a significant threat to custard apple production.

The use of resistant cultivars is one of the most economical and effective strategies for controlling plant diseases. With this objective, custard apple genotypes available at the All India Co-Ordinated Research Project on Arid Zone Fruits (Fig and Custard Apple) in Jadhavwadi were screened in 2022 using various methods to identify sources of resistance and determine the most effective screening technique for fruit rot disease.

Material and Methods

Thirty custard apple genotypes from the All India Co-Ordinated Research Project on Arid Zone Fruits (Fig and Custard Apple) at Jadhavwadi, Pune, were evaluated during 2022 to screen the genotypes against resistance of fruit rot disease. The screening was conducted using the attached fruit culture (AFC) method under controlled field conditions, as well as under natural field conditions.

a. Screening by Attached Fruit Culture (AFC)

The attached fruit culture on different custard apple genotypes was carried out at AICRP on AZF (Fig and custard apple), Jadhavwadi, Pune and disease reactions were recorded. Four fruits of each variety were tagged and bagged. Two fruits were inoculated by mycelial bits inoculation method (MBIM) and other two fruits were inoculated by micro droplet inoculation method (MDIT). The fruits were wounded at stem end by pin prick method and inoculated by using combination of two methods like application of mycelial bits (MBIM) of uniform size (5 mm diameter) on wounded fruit epidermis (Rocha *et al.* 1998) and micro droplet inoculation technique (MDIT) given by Munaut *et.al.* (1997) with spore suspension having 105 conidia per ml. The purpose of using combination of two methods was to have maximum infection of disease. The mycelial discs were placed in inverted position i.e. side of fungal growth on wounded portion and covered with small wet cotton swab to provide moisture for conidial germination and infection. After inoculation fruits were bagged with polythene bags containing cotton swab, saturated with sterile water at the bottom of the bag. During infection and disease development period the relative humidity ranged from 69 to 98 percent and temperature in bag 22 to 30°C. The mycelial bit and cotton swab kept on wounded portion were removed two days after inoculation. Required control set of un-inoculated fruits was provided. The observations regarding latent period were noted beginning at 48 hours from inoculation till appearance of visible symptoms of disease at 24 hours interval. The observations on symptom development were recorded every day after inoculation of fruits.

b. Screening under natural field conditions

The fruit rot disease was studied in field under natural conditions. Custard apple genotypes were observed critically for fruit rot symptoms and using (0 to 7) (Gaikwad, 2002) grade score scale the disease intensity was calculated. The fruit rot severity was recorded by using (0-7) grade scale. The Percent disease intensity (PDI) was calculated by using the formula given by McKinney (1923).

$$PDI = \frac{\Sigma \text{ numerical rating}}{\text{Total no. of fruits observed x maximum grade (}i.e.\text{ 7)}} \times 100$$

Results and Discussion

Attached Fruit Technique (in vivo)

Thirty custard apple genotypes were screened under artificial epiphytotics by attached fruit technique by inoculating each genotype by two inoculation methods; Mycelial bit inoculation method (MBIM) and Micro droplet inoculation technique (MDIT). The data (Table 1) revealed that the treatment differences and their interactions were statistically significant.

A. Mycelial Bit Inoculation Method (MBIM)

Latent Period (LP)

The data presented in Table 1 revealed that the there is significant difference among the different genotypes and latent period. The minimum of 59.0 hrs to maximum up to 115.0 hrs latent period was observed in different custard apple genotypes. The highest latent period (115.0 hrs) was noticed in the Vrudheshwar-3 genotype. The custard apple genotypes Verul-2 (113.0 hrs) and Karkhel (111.0 hrs) were at par with Vrudheshwar-3. The minimum of 59.0 hrs latent period was observed in NMK-1 (Golden) followed by Hyderabad Selection (61.50 hrs) and were at par with each other. The commercial varieties under cultivation have reported latent period of Phule Purandar (90.0 hrs), Balanagar (75.00 hrs), TP-7 (89.0 hrs) and Purandar local (66.0 hrs). The higher la-

Disease rating scale used for recording fruit rot severity

Disease Score	Fruit area infection (%)	Symptoms under		Reactions
		Field	*In vitro*	
0	-	Nil	Nil	Immune
1	<1	Healthy looking fruits, only minute black, pin point, few spots, sometimes yellowish specks may be observed	Healthy looking fruits, only minute black, pin point , few spots, sometimes yellowish specks may be observed	Highly resistant (HR)
2	1.01 to 10.0	Fruits with small, light brownish-black spots of about 0.5 to 1.0 mm in diameter and 5 to 20 spots	Fruits with small, brown to dark brown discoloured area of about 0.5 to 2.0 mm in diameter with or without yellow halo	Resistant (R)
3	10.01 to 20.0	Fruits with small, slightly sunken reddish brown spots of 1.0 to 2.0 mm in size and 10 to 25 spots	Light violet to black discolouration of about 5 to 10 mm in diameter without any fungal growth	Moderately resistant (MR)
4	20.01 to 30.0	Fruits with medium sized moderately sunken light violet to blackish spots of about 2 to 4 mm diameter and 20 to 50 spots	Light violet-black discolouration of about 10 to 20 mm but < 30% fruit surface infection with or without fungal growth	Moderately susceptible (MS)
5	30.01 to 40.0	Fruits with medium to large sized, sunken violet – black spots of about 3 to 8 mm in diameter and 50 to 100 spots scattered all over the fruit, with or without sub-epidermal acervuli	Fruits with violet – black discoloration of about 20-30 mm in diameter, but <40 per cent area of fruit with scanty to moderate ashy-white fungal growth with or without acervuli	Susceptible (S)
6	40.01 to 50.0	Fruits with large deeply sunken , dark violet- black spots of 5 to 8 mm in size and few to many (up to 190) isolated but adjoining spots with sub-epidermal acervuli	Fruits with dark violet – black discoloration of about 30-40 mm in diameter, but <50 per cent area of fruit surface, with good, pinkish- white fungal growth containing acervuli of pathogen	
7	>50.01	Fruits with several typical anthracnose type spots or dark violet to black spots which coalesce with each other resulting into blackening of fruits (dry fruit rot) with numerous orange to black, pin point sub-epidermal fungal bodies (acervuli)	Fruits with dark violet – black to brownish discoloration covering >50 per cent area of fruit surface, with luxuriant orange – white fungal growth containing numerous acervuli of the pathogen, finally resulting into hard, compact, dry fruit mass	Highly susceptible (HS)

tent period results in to slow disease development. Hence, custard apple genotypes Vrudheshwar-3, Verul-2, Karkhel, Vrudheshwar-4, Vrudheshwar-2, Telgaon Local, Humnabad Local and Dhanagarawadi-3 possess slow disease development characters.

Per cent Disease Intensity (PDI)

The observations (Table 1) showed that none of the variety or genotype was free or resistant to fruit rot disease. The minimum of 7.50 per cent disease intensity was observed in Vrudheshwar-3. It was at par with Verul-2 (8.15 %) and followed by Karkhel, Vrudheshwar-4, Vrudheshwar-2, Telgaon Local, Humnabad Local and Dhanagarawadi-3 genotypes and showed moderately resistant reaction to disease. Remaining of the germplasm showed moderately to highly susceptible reaction. The genotypes NMK-1 (Golden) recorded maximum of 50.40 per disease severity and exhibited highly susceptible reaction to the fruit rot disease.

B. Micro Droplet Inoculation Technique (MDIT)

Latent Period (LP)

The observations (Table 1) divulge that the there is significant difference among the different genotypes in latent period was observed. The minimum of 73.0 hrs to maximum up to 117.50 hrs latent period was observed in different custard apple genotypes. The highest latent period (117.50 hrs) was noticed in the Vrudheshwar-3 which was at par with Verul-2 (117.0 hrs) and Karkhel (117.0 hrs). The next best genotypes were Vrudheshwar-4, Humnabad Local, Vrudheshwar-2, Dhanagarawadi-3, Phule Purandar, Dhanagarawadi-7 and Purandar Local. The minimum latent period was noticed in NMK-1 (Golden) (73.0 hrs).

Per cent Disease Intensity (PDI)

The observations (Table 1) showed that none of the variety or genotype was free or resistant to fruit rot disease. The minimum of 5.90 per cent disease intensity was observed in Vrudheshwar-3 genotype and showed resistant reaction to disease. This genotype was at par with Verul-2 (6.60%) and Karkhel (7.50%) which also showed resistant reaction to fruit rot disease. The next best genotypes were Vrudheshwar-4, Humnabad Local, Vrudheshwar-2, Dhanagarawadi-3, Phule Purandar, Dhanagarawadi-7 and Purandar Local which showed moderately resistant reaction to disease The genotype NMK-1 (Golden) recorded 43.60 per cent disease intensity followed by Hyderabad selection recorded 43.30 per cent disease intensity and were at par with each other and showed highly moderately susceptible reaction to the disease..

Screening of custard apple genotypes under natural field condition against fruit rot disease

Thirty custard apple varieties and genotypes were screened under natural conditions for their resistance to *C. gloeosporioides* at All India Coordinated Research Project on Arid Zone Fruits (Fig & Custard apple), Jadhavwadi, Tal.- Purandar, Distt.- Pune during 2022-23 where the disease pressure remains very high.

The observations (Table 2) showed that none of the variety was immune to fruit rot disease. From the data it is revealed that out of 30 genotypes only six genotypes which found resistant to fruit rot disease, were Vrudheshwar-3, Verul-2, Karkhel, Humnabad Local, Dhanagarwadi-3 and Vrudheshwar-4 where they recorded 4.80, 5.91, 6.42, 8.57, 9.09 and 9.55 per cent disease intensity, respectively. Rest 14 genotypes were found moderately resistant to fruit rot disease.

In present investigation it was observed that the fruit rot intensity under natural field condition was very less. The present investigation the genotypes Vrudheshwar-3, Verul-2, Karkhel, Humnabad Local, Dhanagarwadi-3 and Vrudheshwar-4 recorded resistant reaction to fruit rot disease. Padule and Kaulgud (1993) who studied the reaction of 14 different custard apple varieties to fruit rot caused by *C. gloeosporioides* under natural and field condition and found that four varieties *viz.,* Bullock's heart, Island gem, Pink's mammoth and Annona hybrid No. 2 were free from the disease.

The findings of present investigation are in agreement with the earlier work carried out at All India Coordinated Research Project on Arid Zone Fruits (Fig & Custard apple), Jadhavwadi, Tal.- Purandar, Distt.-Pune during 2020, they observed that out of 72 lines screened against *Colletotrichum* leaf blight of custard apple, none of the line was found free. Atemoya and Jalke Khurd were found moderately resistant while rest of the genotypes were found resistant against the disease (Anonymous, 2020). During 2021, out of 72 lines screened against Colletotrichum leaf blight of custard apple at AICRP-AZF, Jadhavwadi, none of the line was found free. 57 germplasm were found resistant while 15 genotypes were found moderately resistant against the disease at Jadhavwadi (Anonymous, 2022).

Conclusion

The various custard apple genotypes were evaluated under natural field conditions using the attached fruit technique. All 30 genotypes tested were found to be infected by the pathogen *Colletotrichum gloeosporioides*. However, the genotypes Vrudheshwar-3, Verul-2, Karkhel, Vrudheshwar-4, Vrudheshwar-2, Telgaon Local, Humnabad Local, and Dhanagarawadi-3 showed moderate resistance using the attached fruit technique. In this study, it was observed that the intensity of fruit rot under natural field conditions was very low. Of the

Table 1. Reaction of different custard apple genotypes to fruit rot disease caused by *C. gloeosporioides* in Attached Fruit Culture (AFC)

S.No.	Custard apple genotypes	MBIM			MDIT		
		LP (hrs)	PDI (%)	Reaction	LP (hrs)	PDI (%)	Reaction
1	Phule Purandar	90.00	25.40	MS	112.00	16.80	MR
2	Purandar Local	66.00	44.40	HS	109.00	19.00	MR
3	Pimple local	87.25	28.30	MS	99.00	23.10	MS
4	Jalkehurd-1	87.00	28.50	MS	100.00	22.50	MS
5	Jalkehurd-2	77.50	33.00	S	95.50	25.75	MS
6	Vrudheshwar-1	84.00	31.75	S	96.00	24.50	MS
7	Vrudheshwar-2	107.00	18.00	MR	114.00	15.40	MR
8	Vrudheshwar-3	115.00	7.50	R	117.50	5.90	R
9	Vrudheshwar-4	107.00	16.40	MR	114.75	12.80	MR
10	Verul-1	86.00	28.50	MS	104.00	22.00	MS
11	Verul-2	113.00	8.15	R	117.00	6.60	R
12	Karkhel	111.00	12.80	MR	117.00	7.50	R
13	Humnabad Local	105.00	19.20	MR	114.00	13.90	MR
14	Patoda-1	83.00	32.80	S	93.25	26.75	MS
15	Patoda-2	87.50	27.60	MS	96.00	24.50	MS
16	Patoda-3	93.00	25.10	MS	107.50	20.40	MS
17	Jahangirmona	77.00	35.30	S	87.00	32.40	S
18	Dhanagarawadi-3	97.00	19.20	MR	112.00	15.50	MR
19	Dhanagarawadi-4	77.00	35.00	S	89.25	32.20	S
20	Dhanagarawadi-6	84.50	31.60	S	97.00	23.70	MS
21	Dhanagarawadi-7	96.50	23.20	MS	111.00	17.30	MR
22	Telgaon Local	107.00	18.60	MR	98.50	23.30	MS
23	NMK-1 (Golden)	59.00	50.40	HS	74.00	43.60	HS
24	Arka sahan	85.00	30.50	S	93.00	28.50	MS
25	Balanagar	75.00	35.50	S	91.00	30.60	S
26	Raidurga	83.50	32.30	S	94.00	26.30	MS
27	APK1	68.00	36.90	S	76.00	33.20	S
28	Sindhan Local	85.00	30.00	MS	97.50	23.50	MS
29	Hyderabad Selection	61.50	47.75	HS	73.00	43.30	HS
30	TP-7	89.00	26.60	MS	96.00	25.20	MS
	SEm±	1.74	1.35		2.54	0.86	
	CD (0.05)	5.06	3.92		7.40	2.50	
	CV (%)	2.79	6.80		3.60	5.31	

MBIM: Mycelial Bit Inoculation Method MDIT: Micro Droplet Inoculation Technique

Table 2. Screening of custard apple genotypes under natural field condition against fruit rot disease

S.No.	Genotypes	PDI (%)	Reaction	S.No.	Genotypes	PDI (%)	Reaction
1	Phule Purandar	10.92 19.26	MR	16	Patoda-3	15.93 23.49	MR
2	Purandar Local	24.86 29.89	MS	17	Jahangirmona	25.26 30.14	MS
3	Pimple local	16.97 24.29	MR	18	Dhanagarawadi-3	9.09 17.54	R
4	Jalkehurd-1	16.97 24.31	MR	19	Dhanagarawadi-4	24.29 29.45	MS
5	Jalkehurd-2	20.59 26.55	MS	20	Dhanagarawadi-6	18.46 25.43	MR
6	Vrudheshwar-1	20.00 19.39	MR	21	Dhanagarawadi-7	12.79 20.94	MR
7	Vrudheshwar-2	11.03 12.63	MR	22	Telgaon Local	18.70 25.61	MR
8	Vrudheshwar-3	4.8 17.95	R	23	NMK-1 (Golden)	40.00 39.22	S
9	Vrudheshwar-4	9.55 24.44	R	24	Arka sahan	27.03 31.30	MS
10	Verul-1	17.14 14.04	MR	25	Balanagar	29.70 33.00	MS
11	Verul-2	5.91 14.67	R	26	Raidurga	20.00 26.53	MR
12	Karkhel	6.42 17.01	R	27	APK1	26.28 30.80	MS
13	Humnabad Local	8.57 30.14	R	28	Sindhan Local	17.33 24.58	MR
14	Patoda-1	20.00 26.52	MR	29	Hyderabad Selection	35.71 36.66	S
15	Patoda-2	18.75 25.63	MR	30	TP-7	24.44 29.56	MS
			SEm± 0.60 CD (0.05) 1.73 CV (%) 5.37				

Note: Figures in bold faces are arc sin values

HR : Highly resistant (>1.00 %)
R : Resistant (1.00 to 10.00 %)
MR : Moderately resistant (10.01 to 20.00 %)
MS : Moderately susceptible (20.01 to 30.00 %)
S : Susceptible (30.01 to 40.00 %)
HS : Highly susceptible (>40.00 %)

30 genotypes, Vrudheshwar-3, Verul-2, Karkhel, Humnabad Local, Dhanagarwadi-3, and Vrudheshwar-4 demonstrated resistance against fruit rot under natural field conditions.

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Research Article

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Influence of weed control treatments on available soil nutrient and plant growth parameters of guava (*Psidium guajava L.*)

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ABSTRACT

This study aimed to evaluate the effects of different weed control methods on soil health and growth parameters in guava cultivation. In this study, 9 years old guava plants of cultivar L-49 at CCSHAU, Hisar were selected during the years 2019-20 and 2020-21. A total of twenty-one treatments were applied on guava trees. Soil and leaf nutrient levels were assessed along with growth parameters including plant height, canopy spread, chlorophyll content anwwd leaf area. Among herbicides, glyphosate (1.26 kg/ha) + carfentrazone (20 g/ha) resulted in the highest levels of N (261.77 and 263.86 kg/ha), Zn (6.79 and 6.80 mg/kg), and Fe (2.26 and 2.28 mg/kg) and glyphosate (1.26 kg/ha) + oxyfluorfen (100 g/ha) led to the maximum levels of P (30.20 and 31.27 kg/ha) and K (298.67 and 299.66 kg/ha) respectively. The maximum leaf area (52.21 cm^2 and 54.56 cm^2) and the greatest increase in plant spread (ranging from 6.12% to 7.15%) were recorded in the treatment with glyphosate (1.26 kg/ha) combined with carfentrazone (20 g/ha). The highest increases in plant height were observed with the application of glyphosate (1.26 kg/ha) combined with carfentrazone (20 g/ha) and glyphosate (1.26 kg/ha) combined with oxyfluorfen (100 g/ha), with percentage increases ranging from 6.91% to 7.05% and 6.90% to 7.07%, respectively. Additionally, manual weeding and mulching also resulted in better growth parameters, including increased plant height and canopy spread.

Introduction

Guava (*Psidium guajava* L.) stands out as a highly nutritious and profitable crop, underscoring the critical need for efficient weed management strategies to ensure optimal growth and high-quality fruit yield. In India, guava cultivation spans across 315 thousand hectares, yielding approximately 4916 thousand metric tonnes of produce (Anonymous, 2021-22). Surpassing damages inflicted by other agricultural pests, weeds account for significant losses in guava cultivation (Abouziena and Haggag, 2016). Weeds can reduce yield by 34 % (Jitender *et al.*, 2021), 35 % (Nibhoria *et al.*, 2021) and 53% (Nibhoria *et al.*, 2022) by competing with crop for water, nutrients and space. Weed roots are known to release allelopathic compounds that hinder the growth and productivity of the main crop while also providing shelter to insect pests and microorganisms (Chatha and Chanana, 2007).

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Weed control and crop establishment should be postponed until the primary flush of weed emergence has subsided, allowing the seedbank in the topsoil to deplete and reducing future weed growth (Bond and Grundy, 2001). Seed germination and weed emergence can be influenced by factors such as soil temperature, daily temperature fluctuations, soil moisture, light exposure, nitrate levels, and the gaseous composition of the soil (Merfield, 2013). Herbicidal approaches are gaining prominence due to their cost-effectiveness in weed management. Herbicides play a crucial role in minimizing weed infestation and maximizing yield (Ashiq *et al.,* 2007). However, the effectiveness of herbicides is contingent upon various factors such as soil type, environmental conditions, herbicide dosage and the susceptibility of non-target species.

Material and Methods

The experiment was conducted at the experimental orchard of Chaudhary Charan Singh Haryana Agricultural University, located in Hisar, during the years 2019 and 2020. A total of twenty-one treatments, each with three replications, were employed using a randomized block design. The experimental location is situated at latitude of 29°10'N, longitude 75°46'E and altitude 215.2 m above mean sea level. The experiment was conducted on nine-year old plants of the L-49 cultivar, planted at 6m x 6 m spacing. The treatments comprised of - T_1 (Glyphosate @ 1.68 kg/ha), T_2 (Carfentrazone @ 20 g/ha), T_3 (Oxyfluorfen @ 150 g/ha), T_4 (Glufosinate @ 500 g/ha), T_5 (Pendimethalin @ 1.5 kg/ha), T_6 (Paraquat @ 0.9%), T_7 (2,4-D @ 1.0 kg/ha), T_8 (Glyphosate @ 1.26 kg/ha + carfentrazone @ 20 g/ha), T_9 Glyphosate (1.26 kg/ha + oxyfluorfen 100 g/ha), T_{10} (Glyphosate @ 1.2 kg/ha + 2,4-D @ 50 g/ha), T_{11} (Glyphosate @ 1.26 kg/ha + pendimethalin @ 1.0 kg/ha), T_{12} (Glyphosate @ 1.26 kg/ha + paraquat @ 0.6%), T_{13} (Glufosinate @ 375 g/ha + pendimethalin @ 1.0 kg/ha), T_{14} (Glufosinate @ 375 g/ha + oxyfluorfen @ 100 g/ha), T_{15} (Glufosinate @ 375 g/ha + paraquat @ 0.6%), T_{16} (Paraquat @ 0.6% + pendimethalin @ 1.0 kg/ha), T_{17} (Mechanical weeding after 30, 60 and 90 Days after application), T_{18} (Mulching with black polythene), T_{19} (Weedy check), T_{20} (Weed free) and T_{21} (Three times hand weedings).

The available nitrogen content in the soil was determined using the Alkaline Permanganate Method proposed by Subbiah and Asija (1956). Phosphorus availability was assessed following the procedure outlined by Olsen *et al.* (1954). The soil's available potassium was measured using neutral normal NH_4OAC solution and a Flame photometer, as described by Hanway and Heidal (1952). Zinc and iron extractable by DTPA were estimated according to the method outlined by Lindsay and Norvell (1978). Leaf area was measured using a Leaf Area Meter. Chlorophyll content was determined using the DMSO method as described by Sawhney and Singh (2002). Plant height was measured in meters using a measuring pole, reaching the maximum point of height. The distance between the points where most branches of the tree had grown in the east-west and north-south directions was measured using a measuring pole as well.

Results and Discussion

Soil nutrients

Different weed control treatments significantly influenced the availability of nitrogen (N), phosphorus (P), potassium (K), zinc (Zn), and iron (Fe). Under weed-free conditions, the availability of N (263.33 and 263.33 kg/ha), P (31.34 and 31.52 kg/ha), K (302.20 and 303.57 kg/ha), Zn (6.83 and 6.83 mg/kg) and Fe (2.30 and 2.31 mg/kg) was the highest during 2019 and 2020, respectively (Table 1). Among herbicidal treatments, glyphosate (1.26 kg/ha) + carfentrazone (20 g/ha) resulted in the highest levels of N (261.77 and 263.86 kg/ha), Zn (6.79 and 6.80 mg/kg), and Fe (2.26 and 2.28 mg/kg). Glyphosate (1.26 kg/ha) + oxyfluorfen (100 g/ha) led to the maximum levels of P (30.20 and 31.27 kg/ha) and K (298.67 and 299.66 kg/ha).

Conversely, the lowest available nutrient levels were observed in the weedy check treatment with N (224.12 and 226.00 kg/ha), P (17.33 and 17.33 kg/ha), K (256.33 and 258.77 kg/ha), Zn (6.51 and 6.53 mg/kg) and Fe (2.08 and 2.10 mg/kg) during both years, respectively. Similarly, Palma *et al.* (2002) noted a positive impact of herbicidal spray on the performance of grape cv. Italia, with vines showing no symptoms of water or nutrient deficiency.

Leaf nutrients

In this investigation, the various weed control methods exhibited non-significant impact on the nutrient's composition of guava leaves. However, the weed-free treatment showed numerically higher levels of nitrogen (N), phosphorus (P), and potassium (K) with concentrations of 1.76% and 1.77%, 0.18% and 0.19%, and 1.39% and 1.41% respectively, across both the years 2019 and 2020. Conversely, the weedy check treatment yielded the lowest N, P, and K levels, measuring 1.58% and 1.61%, 0.16% and 0.18% and 1.16% and 1.18% respectively, during the same period. These findings align with Wright *et al.* (2003) who reported similar results regarding orchard floor vegetation's negligible influence on citrus leaf nutrient concentrations. Conversely, studies on apple orchards by Akanda *et al.* (1997), Cerda *et al.* (1999) and Banaszkiewicz and Kopyutowski (2003) indicated that glyphosate application boosted leaf nutrient content.

Table 1. Effect of different herbicides on available N, P, K, Zn and Fe in soil of guava cv. L-49 orchard

Treatment	N (kg/ha)		P (kg/ha)		K (kg/ha)		Zn (mg/kg)		Fe (mg/kg)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
T1: Glyphosate (1.68 kg/ha)	256.57	257.67	27.80	28.50	295.56	296.51	6.76	6.77	2.22	2.24
T2: Carfentrazone (20 g/ha)	249.28	251.33	24.21	25.79	290.44	291.74	6.72	6.74	2.21	2.22
T3: Oxyflourfen (150 g/ha)	252.33	254.56	25.33	26.40	291.31	293.55	6.74	6.76	2.22	2.23
T4: Glufosinate (500 g/ha)	232.55	235.21	26.28	27.33	293.67	295.78	6.75	6.76	2.22	2.23
T5: Pendimethalin (1.5 kg/ha)	224.21	226.60	18.22	19.45	274.89	276.67	6.64	6.65	2.14	2.16
T6: Paraquat (0.9%)	231.96	233.67	19.41	20.67	277.67	277.70	6.65	6.66	2.15	2.16
T7: 2,4-D (1.0 kg/ha)	247.93	250.33	24.33	25.33	289.37	290.59	6.72	6.74	2.21	2.22
T8: Glyphosate (1.26 kg/ha) + carfentrazone (20 g/ha)	261.77	263.86	29.22	30.20	297.63	299.51	6.79	6.80	2.26	2.28
T9: Glyphosate (1.26 kg/ha) + oxyflourfen (100 g/ha)	259.51	260.40	30.20	31.27	298.67	299.66	6.78	6.80	2.20	2.26
T10: Glyphosate (1.26 kg/ha) +2,4-D (750 g/ha)	246.33	248.00	23.45	25.67	286.67	287.61	6.72	6.73	2.20	2.21
T11: Glyphosate (1.26 kg/ha) + pendimethalin (1.0 kg/ha)	257.44	258.33	28.00	29.53	296.56	298.66	6.77	6.79	2.23	2.25
T12: Glyphosate (1.26 kg/ha) + paraquat (0.6%)	242.67	244.29	22.67	24.33	282.67	283.32	6.69	6.70	2.19	2.20
T13: Glufosinate (375 g/ha) + pendimethalin (1.0 kg/ha)	237.67	239.67	20.00	21.67	276.33	279.34	6.67	6.69	2.16	2.17
T14: Glufosinate (375 g/ha) + oxyflourfen (100 g/ha)	239.33	240.61	21.67	23.67	281.33	282.59	6.68	6.70	2.18	2.19
T15: Glufosinate (375 g/ha) + paraquat (0.6%)	238.51	238.33	21.33	22.78	280.33	281.62	6.68	6.69	2.17	2.18
T16: Paraquat (0.6%) + pendimethalin (1.0 kg/ha)	235.67	236.64	19.54	22.33	275.33	278.65	6.66	6.67	2.15	2.17
T17: Mechanical weeding after 30,60,90 days after application	262.33	264.33	30.75	31.50	300.37	302.44	6.80	6.82	2.28	2.30
T18: Mulching with black polythene	258.81	260.33	28.19	29.84	295.33	297.88	6.77	6.79	2.25	2.27
T19: Weedy	224.12	226.00	17.33	17.33	256.33	258.74	6.51	6.53	2.08	2.10
T20: Weed free	266.33	268.33	31.34	31.52	302.20	303.57	6.83	6.83	2.30	2.31
T21: Three times hand weeding	252.45	256.77	27.82	28.67	293.33	295.67	6.76	6.79	2.25	2.26
SEm±	1.78	1.48	1.13	1.70	1.39	1.56	0.02	0.01	0.03	0.01
CV (%)	1.25	1.03	7.92	11.26	0.84	0.93	0.63	0.36	2.26	1.02
CD at 5%	5.11	4.23	3.25	4.84	3.98	4.47	0.07	0.04	0.08	0.04

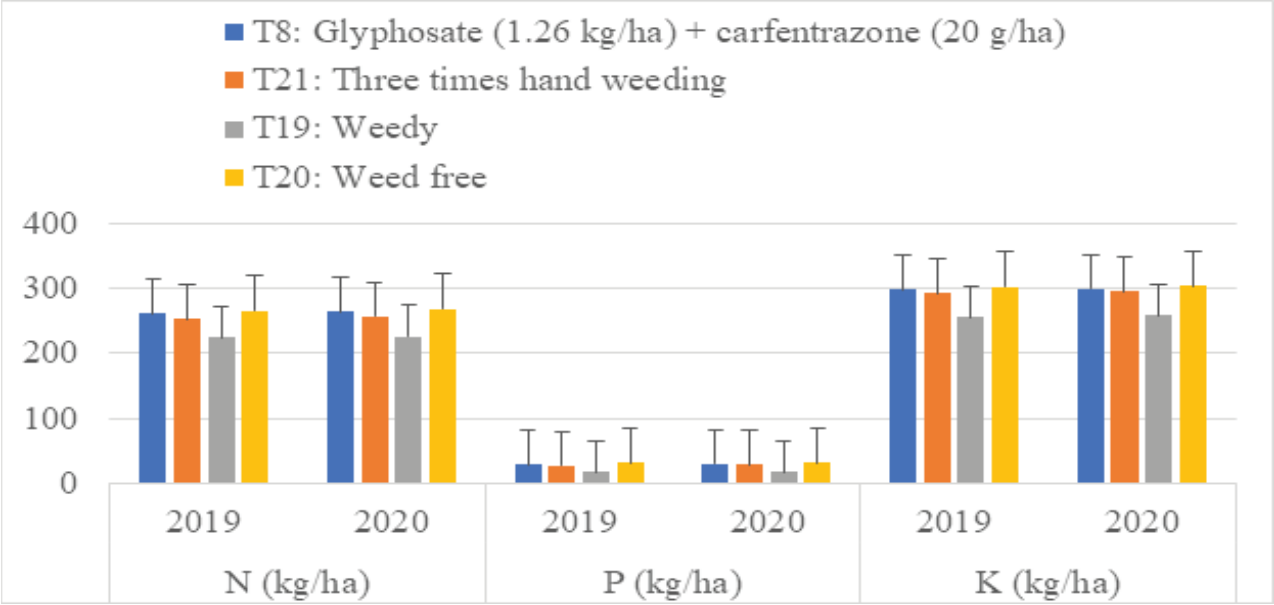

Fig. 1. Effect of different herbicides on available N, P and K in soil of guava cv. L-49 orchard

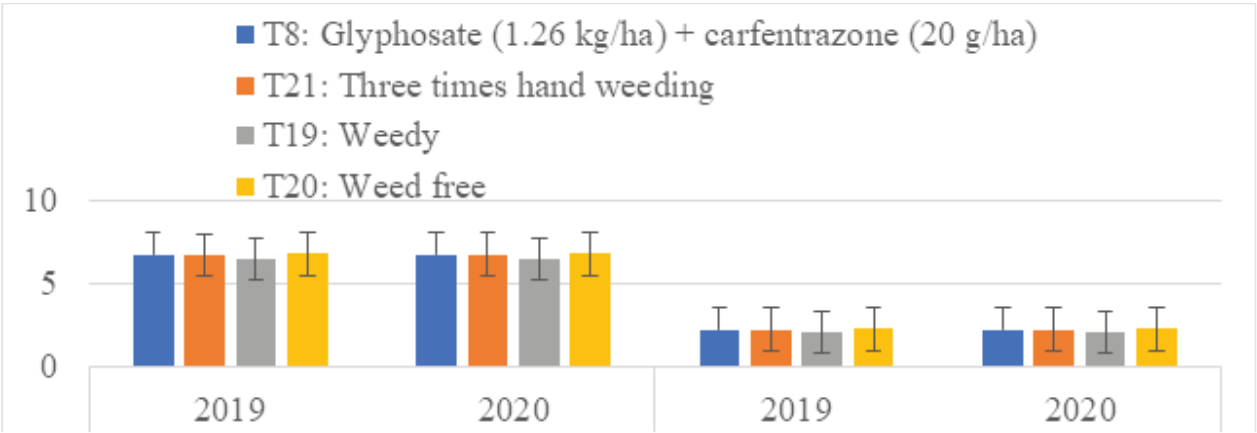

Fig. 2. Effect of different herbicides on available Zn and Fe in soil of guava cv. L-49 orchard

Table 2. Effect of different herbicides and other weed management treatments on per cent increase in growth and chlorophyll in leaves of guava cv. L-49

Treatment	Plant height (%)		Plant spread (%)				% increase in chloro-phyll		Leaf area (cm^2)	
			EW		NS					
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
T1: Glyphosate (1.68 kg/ha)	6.83	6.98	6.98	7.00	5.66	5.78	14.37	16.96	48.51	50.46
T2: Carfentrazone (20 g/ha)	6.75	6.90	6.81	6.92	5.48	5.59	12.75	12.31	45.22	46.58
T3: Oxyflourfen (150 g/ha)	6.78	6.92	6.88	6.97	5.52	5.60	13.35	13.72	46.51	47.86
T4: Glufosinate (500 g/ha)	6.81	6.94	6.92	7.00	5.57	5.63	13.61	15.09	47.44	49.68
T5: Pendimethalin (1.5 kg/ha)	6.51	6.71	6.43	6.48	5.02	5.08	4.14	2.74	31.40	33.22
T6: Paraquat (0.9%)	6.54	6.72	6.47	6.51	5.08	5.14	4.86	3.77	32.69	34.21
T7: 2,4-D (1.0 kg/ha)	6.73	6.88	6.77	6.89	5.42	5.52	7.55	5.59	43.22	45.35
T8: Glyphosate (1.26 kg/ha) + carfentrazone (20 g/ha)	6.91	7.05	7.07	7.15	6.12	6.20	22.95	22.84	52.21	54.56
T9: Glyphosate (1.26 kg/ha) + oxyflourfen (100 g/ha)	6.90	7.07	7.04	7.11	6.10	6.21	18.85	19.78	52.00	53.21
T10: Glyphosate (1.26 kg/ha) +2,4-D (750 g/ha)	6.70	6.85	6.71	6.82	5.35	5.48	11.01	11.28	41.30	43.55
T11: Glyphosate (1.26 kg/ha) + pendimethalin (1.0 kg/ha)	6.88	7.01	7.00	7.05	5.62	5.74	15.34	17.99	50.33	52.35
T12: Glyphosate (1.26 kg/ha) + paraquat (0.6%)	6.68	6.83	6.67	6.69	5.29	5.36	7.47	7.79	40.54	42.31
T13: Glufosinate (375 g/ha) + pendimethalin (1.0 kg/ha)	6.59	6.75	6.53	6.62	5.14	5.21	11.12	9.46	35.55	36.42
T14: Glufosinate (375 g/ha) + oxyflourfen (100 g/ha)	6.65	6.81	6.58	6.66	5.22	5.31	10.79	10.30	38.98	39.21
T15: Glufosinate (375 g/ha) + paraquat (0.6%)	6.60	6.77	6.54	6.64	5.19	5.26	8.96	9.16	36.42	38.24
T16: Paraquat (0.6%) + pendi-methalin (1.0 kg/ha)	6.57	6.74	6.50	6.57	5.11	5.19	7.94	8.62	33.21	35.64
T17: Mechanical weeding after 30,60,90 days after application	6.93	7.09	7.08	7.17	6.16	6.26	24.23	23.96	52.21	54.56
T18: Mulching with black polythene	6.96	7.07	7.05	7.13	6.14	6.22	21.33	22.60	51.25	53.36
T19: Weedy	5.51	5.56	6.31	6.32	5.00	5.02	0.09	0.00	28.21	30.14
T20: Weed free	6.98	7.15	7.12	7.20	6.19	6.30	26.75	25.12	56.21	58.51
T21: Three times hand weeding	6.92	7.04	7.01	7.10	6.10	6.18	20.86	20.90	50.00	52.36
SEm±	0.05	0.04	0.04	0.03	0.04	0.05	0.22	0.26	1.46	1.50
CV (%)	1.26	1.01	0.94	0.87	1.27	1.46	2.26	2.29	5.81	5.72
CD at 5%	0.15	0.12	0.11	0.10	0.12	0.14	0.63	0.74	4.21	4.31

spectively. While it was lowest in weedy check *i.e.* zero percent during both the years. The results are in accordance with the findings of Pathak *et al.* (2007) who observed stimulatory effect of glyphosate and paraquat application on chlorophyll content in guava.

Plant height and plant spread

The percentage increase in plant height was notably highest in the weed-free treatment, reaching 6.98% and 7.15% over the two years (Table 2). Among herbicidal treatments, glyphosate (1.26 kg/ha) + carfentrazone (20 g/ha) and glyphosate (1.26 kg/ha) + oxyflourfen (100 g/ha) both demonstrated significant increases in plant height, with percentages ranging from 6.91and 7.05% and 6.90% to 7.07% during both years respectively. Conversely, the weedy check consistently showed the lowest percentage increase in plant height, ranging from 5.51% to 5.56% across both years.

Regarding plant spread, the weed-free treatment exhibited significantly higher increases in both the east-west (EW) and north-south (NS) directions, ranging from 6.19% to 7.20%. Among herbicides, glyphosate (1.26 kg/ha) + carfentrazone (20 g/ha) also showed notable increases in plant spread, ranging from 6.12% to 7.15%. Conversely, the weedy check displayed the least increase in plant spread, with percentages ranging from 5.00% to 6.32% in EW and NS directions, respectively.

The observed increases in plant height and spread can be attributed to effective weed population reduction, leading to improved nutrient and water availability due to various weed control treatments. These findings are consistent with Pathak *et al.* (2007) who demonstrated that the application of glyphosate before and after sowing increased guava plant height, while post-emergence application reduced it in guava seedlings.

Conclusion

The findings of the investigation highlighted the importance of selecting appropriate weed control methods to enhance soil health and optimize growth parameters in guava cultivation. The maximum soil nutrients, leaf area and growth parameters were found in weed free treatment. Among herbicides, glyphosate (1.26 kg/ha) + carfentrazone (20 g/ha) treatment was found effective for soil nutrient status (N: 261.77 and 263.86 kg/ha; Zn: 6.79 and 6.80 mg/kg, and Fe: 2.26 and 2.28 mg/kg); leaf area (52.21 and 54.56 cm^2) and other parameters in improving the growth of guava.

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Research Article

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Seed priming and environmental effects on germination and seedling vigour in Aonla (*Emblica officinalis Gaertn.*)

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ABSTRACT

Aonla, an important indigenous minor fruit crop, is highly valued for its rich nutrient content. However, the increasing demand for its planting material remains unmet due to poor seed germination and seedling growth. Thus, there is an urgent need to standardize techniques to improve seed germination and seedling development. The current study aims to overcome seed dormancy and to enhance germination in aonla seeds. An experiment was carried out at the College of Horticulture, Venkataramannagudem from January 2022 to May 2022, using a Factorial Randomized Block Design with three replications, comprising 16 treatment combinations. Aonla seeds were treated with GA_3 at concentrations of 300, 500, and 700 ppm for soaking periods of 12 and 24 hours under shade net and polyhouse, along with a control treatment that involved soaking in water for 24 hours. The results indicated that the combination of seed priming with GA_3 @ 500 ppm for 24 hours and polyhouse conditions recorded the best outcomes, with minimum number of days to germinate (7.93 days), number of leaves (29.30), seedling diameter (6.36 mm), root length (17.50 cm) and number of roots per seedling (36.00) and survival percentage (89.32%). This study will help boost the commercial cultivation of aonla, providing significant benefits for growers.

Introduction

Aonla (*Emblica officinalis* Gaertn), commonly known as Indian gooseberry, is a significant fruit crop native to India, thriving across various agro-climatic regions of the country. Revered as a sacred tree, it is referred to as Amritphal in ancient texts. Aonla holds a prominent place in Ayurvedic medicine, particularly in the preparation of Triphala and Chyavanprash. Its hardy nature, high productivity, and nutritional and therapeutic benefits, along with its adaptability for value-added products, have elevated its status as a key fruit of the 21st century (Pathak, 2003). The fruit is renowned for its medicinal properties, offering remedies for various ailments and serving as a base for numerous value-added products. Additionally, aonla is processed into powder, which is con-

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sidered superior to synthetic vitamin C for treating deficiencies. It is cultivated on an estimated 50,000 hectares, yielding an annual production of 1.5 lakh tonnes (Pathak *et al.*, 2003). Seed priming is an effective method for improving seed germination. Pre-sowing treatments with chemicals like GA_3, thiourea, KNO_3, and NAA have been shown to affect germination duration, seedling height, and root and branch development (Dhankar and Singh, 1996; Pawshe *et al.*, 1997; Gholap *et al.*, 2000 and Rajamanickam *et al.*, 2002). Establishing a nursery is essential for providing quality seedlings, and effective management is crucial for success (Krishnan *et al.*, 2014). Practices like ventilated greenhouses, polyhouses, insect-proof net houses, shade net houses, and plastic tunnels enable controlled crop growth. Understanding how plant life history relates to environmental factors helps predict plant establishment and dominance in specific habitats (Murray *et al.*, 2005; Ferreras *et al.*, 2015 and Jelbert *et al.*, 2015).

As a minor fruit crop, aonla has seen limited research on enhancing seed germination and seedling growth using plant growth regulators under various environmental conditions. To address this gap, the present study aims to investigate the effects of seed priming treatments and different growing conditions on the germination and seedling vigor of aonla.

Material and Methods

The experiment was conducted at the College of Horticulture, Venkataramannagudem, Dr. Y.S.R. Horticultural University, West Godavari District. It was carried out from January 2022 to May 2022, using a factorial randomized block design (RBD) with three replications. The experiment included eight treatments *viz.*, water soaking for 24 hours (G_1), GA_3 300 ppm for 12 hours (G_2), GA_3 300 ppm for 24 hours (G_3), GA_3 500 ppm for 12 hours (G_4), GA_3 500 ppm for 24 hours (G_5), GA_3 700 ppm for 12 hours (G_6), GA_3 700 ppm for 24 hours (G_7), and a control (G_8). These treatments were tested under two environmental conditions: shade net (C_1) and polyhouse (C_2). The experiment includes sixteen treatment combinations. Pre-treated seeds were sown in properly filled and labeled polybags and arranged according to the design. Cultural practices such as regular irrigation and weeding were performed as needed. Various observations on seedling germination and growth parameters were recorded periodically. Light intensity in both the shade net and polyhouse environments was measured regularly from the day of sowing up to 120 days after sowing (DAS) using a lux meter.

Results and Discussion

Data were recorded on various parameters, including germination and growth metrics, from five randomly selected seedlings at regular intervals. The analyzed data are presented in Tables 1 and 2, with graphical representations shown in Figures 1-4.

Days taken for initiation of seed germination

Seeds treated with GA_3 at 500 ppm and sown in a polyhouse (T_{13}) germinated rapidly (7.93 days) compared to those sown under a shade net without treatment (T_8), which took 13.87 days. The reduced germination time for GA_3 treated seeds is likely because GA_3 activates the hydrolysis of starch and its translocation, facilitating earlier germination. Similar observations were made by Vasantha *et al.* (2014) in tamarind. Schutz (1999) also noted that optimal temperatures in a polyhouse up to 34°C, enhanced seed germination and seedling growth in Carex species.

Number of leaves per seedling

Interaction of growth regulators and growing conditions has shown significant difference on number of leaves at 30, 60, 90 and 120 DAS. The combination of seed priming with GA_3 @ 500 ppm + 24 h + polyhouse conditions (G_5C_2) recorded highest number of leaves per seedling (7.40, 15.62, 21.91 and 29.30 at 30, 60, 90 and 120 DAS respectively). The increase in the number of leaves per seedling due to GA_3 application might be attributed to GA_3 moving into the shoot apex, enhancing cell division and growth, which in turn promotes the development of young leaves (Salisbury and Ross, 1988). Similar results were reported by El-Dengawy (2005) in loquat and Meena and Jain (2005) in papaya. Protected farming in polyhouses shields crops from sudden weather changes and regulates the internal environment (Maikhuri *et al.*, 2001), thereby promoting the production of more leaves.

Seedling diameter (mm)

Treatment T_{13} recorded the maximum seedling diameter at 2.52 mm, 3.69 mm, 5.10 mm, and 6.36 mm at 30, 60, 90, and 120 DAS, respectively, followed by T_5. The lowest diameters were observed in T_8 (G_8C_1), measuring 1.47 mm, 1.73 mm, 2.32 mm, and 2.89 mm at 30, 60, 90, and 120 DAS, respectively. The increase in stem diameter might be due to GA_3 enhancing osmotic nutrient uptake and boosting growth by promoting cell division, elongation, and multiplication in the cambium tissue of the stem (Mistry and Sitapara, 2020). These findings are consistent with results reported by Ramteke *et al.* (2015) in papaya, Joshi *et al.* (2017) in chironji, and Manthri and Bharad (2017) in guava.

Root length (cm)

Maximum root length (17.50 cm) was recorded in T_{13} (GA_3

Table 1. Effect of seed priming and growing conditions on no. of leaves, seedling diameter, root length and no. of roots per seedling

Treatments		Number of leaves per seedling	Seedling diameter (mm)	Root length (cm)	Number of roots per seedling
T_1: G_1C_1	Water soaking for 24 hrs + shade net	20.13	3.40	12.56	30.12
T_2: G_2C_1	GA_3 300 ppm for 12 hrs + shade net	21.98	4.86	13.78	31.47
T_3: G_3C_1	GA_3 300 ppm for 24 hrs + shade net	25.84	5.54	15.60	33.65
T_4: G_4C_1	GA_3 500 ppm for 12 hrs + shade net	27.32	5.85	16.79	34.56
T_5: G_5C_1	GA_3 500 ppm for 24 hrs + shade net	28.60	6.00	17.20	35.40
T_6: G_6C_1	GA_3 700 ppm for 12 hrs + shade net	23.04	5.36	14.10	32.15
T_7: G_7C_1	GA_3 700 ppm for 24 hrs + shade net	24.48	5.11	14.79	31.87
T_8: G_8C_1	Control + Shade net	19.44	2.89	11.22	28.46
T_9: G_1C_2	Water soaking for 24 hrs + polyhouse	20.87	3.61	12.98	30.57
T_{10}:G_2C_2	GA_3 300 ppm for 12 hrs + polyhouse	22.61	5.01	14.01	31.97
T_{11}:G_3C_2	GA_3 300 ppm for 24 hrs + polyhouse	26.54	5.73	15.98	33.87
T_{12}:G_4C_2	GA_3 500 ppm for 12 hrs + polyhouse	27.94	5.84	17.01	35.04
T_{13}:G_5C_2	GA_3 500 ppm for 24 hrs + polyhouse	29.30	6.36	17.50	36.00
T_{14}:G_6C_2	GA_3 700 ppm for 12 hrs + polyhouse	23.77	5.47	14.56	32.65
T_{15}:G_7C_2	GA_3 700 ppm for 24 hrs + polyhouse	24.87	5.20	14.98	32.00
T_{16}:G_8C_2	Control + polyhouse	20.12	2.95	11.36	28.64
	SEm±	0.050	0.024	0.030	0.035
	CD at 5%	0.146	0.069	0.087	0.102

Table 2. Effect of seed priming and growing conditions on days taken for initiation of germination and seedling survival percentage

Treatments		Days taken for initiation of germination (days)	Survival per cent of seedlings (%)
T_1: G_1C_1	Water soaking for 24 hrs + shade net	12.56	76.84
T_2: G_2C_1	GA_3 300 ppm for 12 hrs + shade net	11.54	80.12
T_3: G_3C_1	GA_3 300 ppm for 24 hrs + shade net	10.41	85.10
T_4: G_4C_1	GA_3 500 ppm for 12 hrs + shade net	9.52	87.86
T_5: G_5C_1	GA_3 500 ppm for 24 hrs + shade net	8.44	89.11
T_6: G_6C_1	GA_3 700 ppm for 12 hrs + shade net	11.98	82.42
T_7: G_7C_1	GA_3 700 ppm for 24 hrs + shade net	11.03	81.89
T_8: G_8C_1	Control + Shade net	13.87	74.60
T_9: G_1C_2	Water soaking for 24 hrs + polyhouse	12.33	79.43
T_{10}:G_2C_2	GA_3 300 ppm for 12 hrs + polyhouse	11.02	80.75
T_{11}:G_3C_2	GA_3 300 ppm for 24 hrs + polyhouse	10.02	85.40
T_{12}:G_4C_2	GA_3 500 ppm for 12 hrs + polyhouse	8.79	88.25
T_{13}:G_5C_2	GA_3 500 ppm for 24 hrs + polyhouse	7.93	89.32
T_{14}:G_6C_2	GA_3 700 ppm for 12 hrs + polyhouse	11.65	83.10
T_{15}:G_7C_2	GA_3 700 ppm for 24 hrs + polyhouse	10.75	82.03
T_{16}:G_8C_2	Control + polyhouse	13.41	75.40
	SEm±	0.027	0.075
	CD at 5%	0.078	0.217

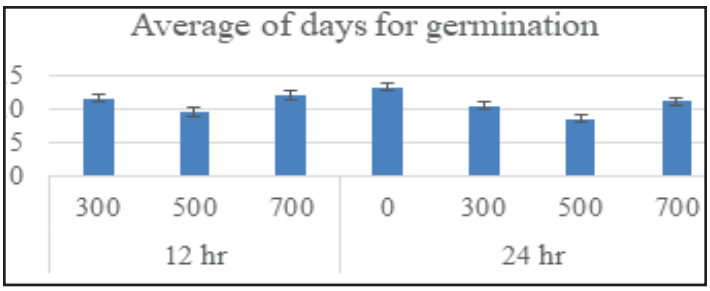

Fig. 1. Effect on average days for germination under shade net

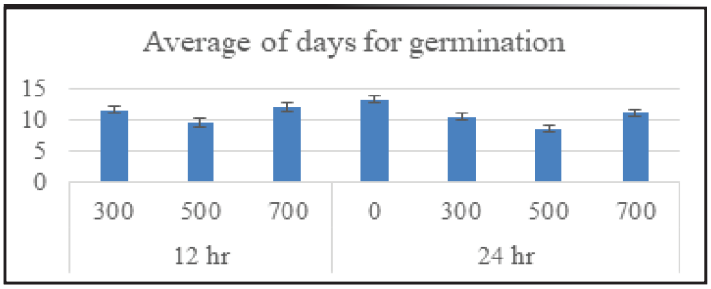

Fig. 2. Effect on survival (%) of seedlings under shade net

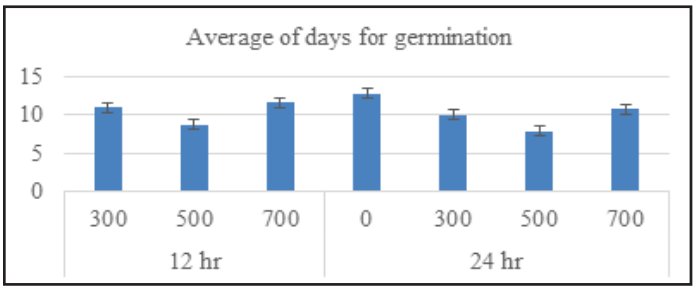

Fig. 3. Effect on average days for germination under polyhouse

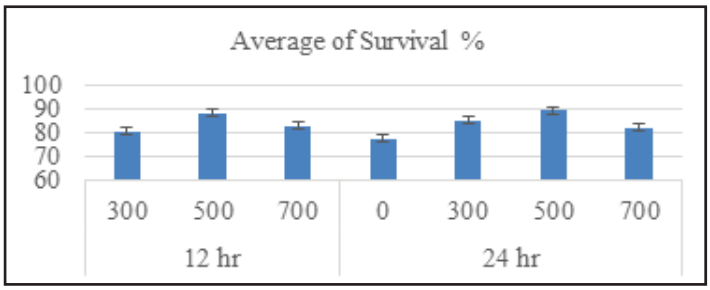

Fig. 4. Effect on survival (%) of seedlings under polyhouse

500 ppm for 24 hrs + polyhouse) whereas, minimum root length (11.22 cm) was recorded in the control T_8 (no soaking + shade net). Seed priming with GA_3 may enhance photosynthetic activity, accelerate translocation, and improve the efficiency of utilizing photosynthetic products, leading to cell elongation and rapid cell division in the growing portions of roots (Surakshitha *et al*., 2014). The highest root length observed in polyhouse seedlings can be attributed to the favorable growth conditions provided by the polyhouse environment. These findings align with those of Ramdas *et al.* (2011), who reported maximum germination and seedling growth of Picrorhiza kurroa under polyhouse conditions compared to open field conditions.

Number of roots per seedling

The combination of seed priming and growing conditions demonstrated a significant difference in the number of roots. Seed priming treatment G_5C_2 recorded the highest number of roots: 14.12, 23.97, 30.02, and 36.00 at 30, 60, 90, and 120 DAS, respectively, followed by G_5C_1. The lowest number of roots, 7.06, 17.60, 23.01, and 28.46 at 30, 60, 90, and 120 DAS, respectively, was observed in G_8C_1. The application of GA_3 enhances the growth rate and promotes the development of hairy roots. The above results are in conformity with findings of Dilip *et al.* (2017a & b) in Kagzi lime and Rangpur lime. The higher number of roots observed in seedlings grown in polyhouses may be attributed to the increased availability of light intensity under polyhouse conditions, which facilitates enhanced growth and development of the plants (Marcelis and Hofman-Eijer, 1993). These results were in confirmatory with earlier findings of Muhammad *et al.* (2004) in guava.

Light intensity (k lux)

The study revealed that light intensity inside the polyhouse was higher compared to that in the shade net. In the polyhouse, maximum light intensity (44280 lux) was observed in May, while minimum (24700 lux) occurred in January. In contrast, in the shade net, maximum light intensity (36250 lux) was recorded in March, with minimum (17450 lux) in January during the study period. Photosynthesis, which produces plant matter, occurs when chlorophyll absorbs light in the green parts of the plant, primarily the leaves (Umesha *et al.*, 2011). The greater incidence of solar radiation under polyhouse conditions is attributed to the superior roof design, enhancing microclimatic conditions that positively influence seedling growth and vigor. These findings are consistent with observations in tomato by Mintu (2018) and in aonla by Verma *et al.* (2019).

Survival per cent of seedlings (%)

The highest seedling survival rate (89.32%) was observed with GA_3 treatment at 500 ppm for 24 hours combined with a polyhouse treatment (T_{13}) which might be due to favourable environmental conditions (Brijwal and Kumar, 2013). These results align with the findings of Supe *et al.* (2012) and Manekar *et al.* (2011) in aonla. However, the lowest survival rate (74.60%) was recorded in the control group under shade

net (T_8). The increase in germination percentage and seedling vigor index due to house's interior maintained an optimal temperature (around 28°C), promoting seedling growth and development by gradually increasing air temperature due to the greenhouse effect, which led to higher seedling survival rates (Kumari *et al*., 2014). These results are consistent with the findings of Verma *et al*. (2019) in aonla.

Conclusion

Based on the results of this experiment, it can be concluded that seeds treated with GA_3 at 500 ppm for 24 hours and sown in a polyhouse (T_{13}) showed the best results in terms of germination parameters, growth parameters, production of vigorous seedlings, and higher survival percentage compared to other seed treatments and growing conditions.

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Review Article

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Ziziphus nummularia (Burm. f.) Wight & Arn.: A versatile array of fruits from the Indian Thar Desert-A review

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ABSTRACT

The recognition of diversity among plant species highlights the importance of utilizing neglected and underutilized plants, which play a crucial role in ensuring food security, providing livestock feed, generating income, and meeting the energy requirements of rural communities. This approach promotes sustainable food security by diversifying our food sources, rather than depending solely on staple crops, which can create a limited food supply and increase vulnerability. Although dietary diversification and the supply of essential micronutrients like vitamins and minerals hold significant promise for reducing risks in agricultural production systems, they remain underexplored in research and development. This neglect may result in genetic erosion. *Ziziphus nummularia* is a plant species whose entire structure-fruits, leaves, branches, and roots-holds considerable economic value in rural communities. For instance, ripe fruits are consumed fresh, leaves serve as fodder, thorny branches are used for fencing farm boundaries, and wood is utilized for fuel and the creation of local agricultural tools, in addition to its applications in traditional medicine. In addition, this plant is capable of thriving under environmental pressures such as high temperatures, significant wind speeds, and low moisture availability, making it appropriate for cultivation in regions with adverse natural conditions, such as deteriorating land and limited water supplies. The limited research conducted on *Z. nummularia* has further complicated efforts to develop superior varieties within this species. In the future, it is crucial to conduct studies that fully leverage the potential of this species. This article is designed to provide a comprehensive overview of *Z. nummularia*, with the intention of inspiring researchers to explore this crop, which is vital in India and other arid and semi-arid areas around the world.

Introduction

The total number of cultivated species worldwide that could be beneficial to humans is estimated to be about 7,000 (Rehm and Espig, 1991, Hammer and Khoshbakht, 2005; Raman, 2006). Kunkel (1984) suggests a higher figure of 12,650, and when ornamental plants are included, Khoshbakht and Hammer (2008) raise this number to 35,000. Nonetheless,

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there is a considerable discrepancy between the available diversity and the diversity that is actually utilized (Prescott and Prescott, 1990). Globally, the commercial cultivation of crops is limited to approximately 150 to 200 significant species, with just 30 of these providing 95% of the food energy needed worldwide (FAO, 1998). Among these, key crops like rice, wheat, maize, and potatoes together make up 45% of the daily food supply across the globe (FAOSTAT, 2012). The FAO (1999) also noted that approximately 18,000 to 25,000 species collected from the wild are used for food. Indigenous fruit trees are especially vital, as they provide essential resources for nutrition, medicinal purposes, cosmetics, fodder, fibers, and fuel. These trees play a critical role in supporting the livelihoods of rural populations, particularly in arid areas where the failure of crops often results in inadequate nutrition for the local communities (Maxwell, 1991).

Over the past decade, the rising interest in neglected and underutilized species has emerged as a constructive reaction to the increasing worries regarding the heavy reliance on a small selection of crops to secure global food supply and stimulate economic growth in the face of global changes (Padulosi *et al*., 1999 and Stamp *et al*., 2012). There is a growing acknowledgment of the significant contributions that these species can make towards agricultural diversity and alleviating poverty (Padulosi *et al.*, 1999 and Frison *et al*., 2006,) While these indigenous plants may be perceived as overlooked or underused worldwide, they are recognized for their significant contributions at local, national, and international levels (Hammer *et al*., 2001). They are integral to local and regional agricultural practices for food sourcing and are essential genetic resources in the global endeavor to sustain biodiversity (Grivetti and Ogle, 2000). Indigenous plant species play a vital role in the rural economy of arid regions in India, where natural scrublands are still abundant (Mann and Saxena, 1981). There is a marked interest among local populations in these plants, which serve multiple functions, including providing food, generating additional income, feeding livestock, offering folk remedies, supplying energy, and contributing to soil conservation, particularly in stabilizing sand dunes (Gebauer *et al.*, 2007).

Despite the acknowledged importance of this indigenous species, it continues to be underexploited and insufficiently appreciated, with its contributions to farmers' livelihoods not adequately incorporated into poverty reduction initiatives (Schreckenberg *et al*., 2006). The world population is estimated to climb to 9 billion people by 2050 (UN Population Division, 2011), requiring an additional increase in food production of 70 per cent to 100 per cent (Godfray *et al*., 2010). In demand of this future foods to meet the needs of an increasing world population the development of alternative crops to improve the range of produce available is needed (El-Siddig *et al*., 1999). The significance of this is especially evident in species capable of adapting to severe environmental conditions such as drought, heat, and salinity stress. One notable example is *Ziziphus nummularia* (Burm.f.) Wight & Arn. This fruit crop is referred to by several local names, including *Jharber* in Hindi, *Aja-priya, Balakapriya*, and *Bhu-kartaka* in Sanskrit, as well as *Chanyabor* in Gujarati, Zariab, and Poast jharberi in Urdu, and Parpalligidda in Pali (Madhya Pradesh) and Karnataka (Verma, 2016). Rural communities in the arid regions of India place significant reliance on this species, which is noted for its importance and has historical references regarding its uses (Pareek, 1978).

There has been minimal research conducted under Indian conditions, and no internationally recognized germplasm collection exists in the country. While efforts have been made to explore its nutritional and pharmacological properties, research on other critical aspects remains insufficient. The seeds are categorized as orthodox, and there is a lack of information concerning their genetic variability and agronomic requirements. This paper seeks to summarize the available information on *Z. nummularia* to foster interest in this crop and to present indigenous knowledge related to its various uses and genetic diversity.

Botany

Ziziphus, a genus within the Rhamnaceae family, comprises around 100 species of deciduous and evergreen trees and shrubs that are distributed across tropical and subtropical regions worldwide (Johnston, 1963). Of these, twelve species are known to be cultivated (Hammer *et al.,* 2001). In the desert regions of India, five or six species are represented, including *Z. glabra*, *Z. mauritiana, Z. rugasus, Z. truncate, Z. nummularia,* and *Ziziphus xylopyrus* (Bhandari, 1978). Among the six species identified, *Z. nummularia* and *Z. mauritiana* are the most commonly dominant in Indian conditions. *Z. mauritiana* is commercially cultivated, while *Z. nummularia* is not and is predominantly found thriving in the wild of the Indian Thar Desert. Although *Z. nummularia* generally grows as a tree, it has adapted to a shrubby form due to significant grazing pressure from both domestic and wild animals during its growth and fruiting stages, as well as the use of its thorny branches for agricultural fencing and wood for tool production, resembling other related species such as *Z. spina-christi* (Obeid and Mahmoud, 1971).

The root system of these plants is extensive and reaches considerable depths. They are classified as thorny shrubs, averaging between 1 and 2 meters in height, with the potential to grow as tall as 6 to 8 meters. The plants are multi-stemmed at the base, with stems and branches that are widely divergent and flexible. Their coloration ranges from purplish to ashy, featuring velvety stipular prickles arranged in pairs. The branches typically exhibit a zigzag formation and are coated in white, complemented by light brown bark. Leaves of this shrub are alternately arranged on short stalks, measuring between 12-18 mm in length and 8-10 mm in width. The upper surface is a deep green and glossy, while the underside

is more or less tomentose and white, with a rounded shape at both the apex and base.

The leaves are serrated and feature 3 to 5 veins that extend from the base. Stipular spines are present in pairs, with one spine being slender and straight, and the other being shorter and recurved. The flowering period typically coincides with the onset of the southwestern monsoons, occurring from July to August, while the fruits reach full ripeness in November and December. The flowers are cream in color and are arranged in short, compact cymes in the axillary position. The calyx exhibits a pubescent texture on its outer surface and has a fissure located roughly halfway down. The lobes are triangular-ovate, and the petals are either cuneate or rounded at the apex. The filaments are deflexed, while the disc comprises ten lobes, each with a pit situated opposite. The style is bifurcated, and the ovary consists of two cells.

The fruits are fleshy drupes that can be either red or black, globose in shape, and less than one centimeter in diameter. They contain limited edible pulp, which is often characterized by an astringent or tart taste. The seeds are smooth, shiny, and brownish, typically found in pairs within the hard stones of the fruit (Orwa *et al*., 2009).

Ecology and distribution

Reports indicate that this species possesses a deep-root system and is capable of storing larger quantities of carbohydrates. The *Ziziphus* genus is well-regarded for its hardiness as a shrub, exhibiting strong resistance to abiotic stresses such as drought, frost, and heat, as well as to various biotic threats like pests and diseases (Paroda and Mal, 1989). Its extensive root zone allows for regeneration even after suffering injuries or damage from, setting it apart from other species such as *Ziziphus mauritiana* and *Z. jujuba* Mill., according to the findings of Kirkbride *et al.* (2006).

The distribution of *Zyzyphus nummularia* is limited to certain regions, specifically Afghanistan, India, Iran, Lebanon, Pakistan, and Zimbabwe, with an exotic presence in Mauritania, Nigeria, and Uganda (Orwa *et al.*, 2009). Thanks to its high adaptability, this shrub can occupy large arid expanses in the Indian desert, even in regions that receive only 150-250 mm of rainfall, covering multiple districts in northwestern India (Jawanda and Bal 1978). This species, *Z. nummularia*, is capable of growing in nearly all soil types, including skeletal soils, gravelly plains, sand dunes, alluvial regions, and rocky landscapes, but it does not thrive in saline patches or certain sand dunes. Large populations of *Z. nummularia* are prevalent in Punjab, Rajasthan, Gujarat, Uttar Pradesh, and Madhya Pradesh (Saxena and Mann, 1981).

In the northwestern regions of India, especially in the arid western Rajasthan, many "Orans" and "Bir" (common village grazing lands) are largely dominated by this shrub. It plays a significant role as a co-dominant species alongside Kair (*Capparis decidua*) in communities found on eroded rocky surfaces, piedmont plains, and pediment plains. Furthermore, *Z. nummularia* can be found in scattered distributions across sandy, undulating hummocky plains, where the predominant vegetation is psammophytic. The arid landscapes of Rajasthan, characterized by their rolling terrain, host a community of *Calligonum polygonoides* and *Ziziphus nummularia*. This combination of species serves as an effective soil binder, exhibiting a moderate to high density ranging from 60 to 302 plants per hectare.

In protected forest areas located on low hills and piedmonts, this species is often found in association with *Acacia senegal*, where plant density varies between 80 and 350 plants per hectare, accompanied by a modest crown cover of 5 to 7 percent. Conversely, in unprotected hilly regions facing significant exploitation, the shrub density is minimal, contributing only 10 to 50 plants per hectare, often in association with other species such as Thor and Euphorbia (Saxena and Mann, 1981).

Notably, some larger orans exhibit a relative dominance of 75 to 90 percent of this species, with the remaining 10 to 25 percent typically occupied by other plants like *Khejri* (*Prosopis cineraria*), Hingota (*Balanites aegyptiaca*), and Kair (*Capparis deciduas*). *Ziziphus nummularia* is commonly found at elevations up to 1700 meters and can endure temperatures reaching 50°C (Kumawat *et al.*, 2018).

Perpetuations

Z. nummularia is capable of reproduction through both sexual and asexual means. In natural settings, it propagates using seeds and root suckers (Kumawat *et al.*, 2018). The cross-pollination of this shrub, primarily conducted by insects and bees, contributes to a high level of genetic variability due to segregation. The process of propagation via seeds reveals considerable genetic variation. This trait of having broad genetic diversity could offer this species a distinct advantage in adapting to challenging and severe environmental conditions.

Z. nummularia seeds feature resilient seed coats that hinder germination. In a controlled environment, seeds generally require 1 to 3 months for germination. To mitigate this challenge in commercial propagation, the seed coats can be gently broken using a hammer or stones, allowing the shelled seeds to be planted thereafter. Seed treatments, particularly scarification, can significantly enhance the germination of these seeds (Moustafa *et al.*, 1998). In a study involving *Z. spina-christi*, it was found that seeds exposed to 97% sulfuric acid for 120 minutes achieved a germination rate of 91%, compared to just 41% for those that were not treated (Saied *et al.*, 2007). Emerging young plants are at risk from browsing animals and require protection, while well-established plants have a significant capacity for regeneration and can withstand considerable levels of browsing. The exploration

of biotechnological approaches for large-scale propagation is still in its early stages, with no commercial cultivars developed or released for these fruit crops.

Additionally, tissue culture protocols represent another promising biotechnological method for propagation. Rathore *et al.* (1992) conducted research on the cloning of *Zizyphus nummularia* from nodal stem explants, achieving the proliferation of five to seven shoots on Murashige and Skoog's (MS) medium that contained 5.0 mg l–1 of 6-benzylaminopurine (BAP) and 0.05 mg l–1 of indole-3-acetic acid (IAA). The shoots produced in vitro were able to be further multiplied on new medium. The study also indicated the feasibility of mass multiplication of *Ziziphus nummularia*, a drought-resistant shrub found in the Indian Desert, through this in vitro technique. Explants derived from shoot tips demonstrate significant potential for multiple shoot proliferation, producing approximately 15 to 20 shoots. This is followed by cotyledonary nodes, which yield around 10 to 15 shoots, nodal regions with 8 to 10 shoots, and hypocotyls that generate 6 to 8 shoots. These observations were made using Murashige and Skoog's (MS) medium enriched with 2.5 mg L-1 kinetin (kn).

Furthermore, rooting can be facilitated in both the original explants and the newly formed shoots by placing them on a filter paper bridge for 12 hours in White's liquid medium containing 8.0 mg per litre Indole Butyric Acid (Mathur *et al*., 1993).

Pharmocological evidences and ethnomedicinal uses

Z. nummularia is recognized as an underutilized plant that warrants additional research. It is a valuable source of nutrition and serves multiple purposes (Oudhia, 2003). The bark is effective in treating boils and is beneficial for dysentery and diarrhea. In the context of Ayurveda, the root of *Z. nummularia* is noted for its bitter and cooling properties, which help alleviate coughs, biliousness, and headaches (Kirthikar and Basu, 1994).

The fruits of *Z. nummularia* are also rich in sugars, vitamin C, and various important minerals. Alkaloids are present in dried fruits, while the bark contains a unique 13-membered N-formylcyclopeptide alkaloid referred to as nummularine-T (Singh and Pandey, 1995). Additionally, the dried leaves of *Z. nummularia* are recognized for a novel dammarane saponin named Zizinummin (Sharma and Kumar, 1983) and various glycosides (Srivastava, 1984). These substances are associated with several beneficial properties, including anticancer, anodyne, pectoral, refrigerant, sedative, styptic, stomachic, and tonic effects. The local populace believes that these fruits can purify the blood and enhance digestion. These substances are also employed for the internal treatment of various conditions such as loss of appetite, anemia, bronchitis, burns, chronic fatigue, diarrhea, hysteria, irritability, and pharyngitis (Chopra *et al*., 1956 and Singh *et al*., 2002).

The fruits are utilized to relieve abdominal pain during pregnancy, act as an antidote for aconite poisoning, and facilitate wound healing. Notably, during the 1869 famine in the Thar desert, these fruits served as a vital food source for thousands of inhabitants. Furthermore, the plants have been reported to exhibit pharmacological effects, including anthelmintic, antitumor, antibacterial, antifertility, abortifacient, sedative, hypnotic, hypoglycemic, and hypolipidemic properties (Bachaya *et al.*, 2009; Kumar *et al.*, 2002; De Boer *et al.*, 2005; Shah *et al.*, 2009; Rauf *et al.*, 2016 and Rajsekharan, 2013).

Major uses

This species is a shrub that holds considerable economic significance and is highly valued by local villagers. It provides essential nutritious feed even during famine conditions when other vegetation has dried up (Purohit and Khan, 1981). In the rural areas of western India, where this species grows naturally, all parts of this species-roots, stems, branches, leaves, fruits, and seeds—are economically beneficial. The mature fruits of *Z. nummularia* consist of 81 to 97% pulp, which includes 12-23% total soluble solids (TSS), 0.13-1.42% acidity, 3.1-14.5% total sugars, 1.4-9.7% reducing sugars, 5.6% sucrose, 1.5% glucose, 2.1% fructose, and 1.0% starch (Jawanda and Bal, 1978).

Roots are extracted for medicinal applications and can also be fashioned into toothbrushes or dried for use as fuel. The stems are transformed into durable furniture and local agricultural implements, such as *Bhai* and *Chokni*, and are also used as firewood. Thorny branches hold significant value, serving as fencing to safeguard agricultural crops from domestic and wild animals. Furthermore, these branches are employed in constructing roofs for shelters, with the dried versions also used for firewood. The leaves provide a nutritious local fodder known as Pala and can be utilized as manure. The species is frequently browsed by animals, which contributes to its bushy growth form. The ripe fruits are particularly enjoyed by local women and children, who consume them directly (Kumar, 2016).

According to Muthana and Shankarnarayan (1978), *Z. nummularia* fodder is the fourth most preferred choice for sheep, following the leaves of Acacia nilotica (Babool), Prosopis cineraria (Khejri), and *Salvadora oleoides* (*Jal*), which occupy the first three positions. Under open grazing conditions, the leaves are a significant source of forage and fodder for animals (Verinumbe, 1993). This becomes especially vital in the dry season when grazing options are limited. Small branches are commonly lopped to serve as fodder for camels and goats during this time and are later repurposed for building thorn fences (Bunderson *et al.*, 1990). Furthermore, a blend of ripe fruits and buttermilk is beneficial in mitigating the effects of opium intoxication.

Various vigor tonics can be formulated by mixing these with additional components. Bark serves as an effective ointment for treating foul sores, while its decoction is commonly utilized for gargling in cases of sore throat and ulcerated gums. The cotyledons are beneficial for addressing eye issues. Additionally, the leaves are employed in the treatment of scabies and various skin conditions. Dried leaves can be burned and inhaled to alleviate symptoms of cough and cold (Saxena and Mann, 1981).

Species conservation and future genetic improvement

Among the various species of Ziziphus, *Z. nummularia* and *Z. rotundifolia* stand out as the most crucial, predominantly located in the arid areas of India. While both are valued for their horticultural qualities, they differ in their morphological traits. This species shows considerable variability across the country. To evaluate the genetic diversity and relationships of Jharber cultivars, modern morphological and molecular markers can be employed, facilitating advancements in breeding initiatives (Yashmin *et al*., 2017). Over the years, both species have been used in studies related to rootstock for cultivated ber (*Z. mauritiana*).

Z. rotundifolia is often preferred over *Z. nummularia* due to its advantageous traits. India is home to a rich genetic diversity of Ziziphus, with around 20 species primarily found in the latitudinal range of 8.5-32.5°N and longitudinal range of 69-84°E. This genetic variation leads to a heterozygous population, which contributes to a wide adaptability to different soil types and climatic conditions, as well as various morphological, physiological, and phenological characteristics, chromosome counts, and resistance to both biotic and abiotic challenges (Awasthi and More, 2008). But however, full exploitation of this potential is still negligible.

Furthermore, the increase in agricultural land to meet food requirements has led to heightened browsing pressure, as well as rampant lopping and collection practices (Anonymous, 2000). To advance conservation efforts, it is crucial to assess and document these plant genetic resources and establish a collaborative research strategy. An effective strategy must be formulated to facilitate successful conservation and promotion through enhanced usage. The conservation of germplasm for this species will act as a genetic reservoir, providing breeders with the opportunity to select new traits aimed at developing cultivars that exhibit desired qualities, such as resilience to biotic and abiotic challenges. The enhancement of diversity within this species will support the crop's adaptive potential and mitigate the effects of unpredictable changes in the environment (Peroni and Hanazaki, 2002; Jackson *et al*., 2007; Hajjar *et al*., 2008 and Frison *et al*., 2011).

Prospective applications

In the dry regions of India, the vegetation primarily consists of short-lived and annual plant species. These plants emerge with the onset of the monsoon rains and complete their life cycle before the season concludes. For grazing communities, perennial species are vital as they offer nourishment once the annual plants have died off. *Ziziphus nummularia* is a key perennial species, demonstrating remarkable adaptation to the harsh dry and hot conditions prevalent in the arid and semi-arid regions of North Western India.

This species maintains its foliage for an extended period and is essential to the desert economy. Currently, there is a lack of effective management strategies for *Z. nummularia*. These plants grow naturally through seed dispersal facilitated by natural agents such as wind, animals, and humans. To enhance the systematic propagation of this tree, thorough research is necessary, including the collection and analysis of plant materials, identification of superior genotypes, development of effective cultivation techniques, and the multiplication and distribution of seedlings to farmers. Establishing large-scale plantations of this species near rural communities would significantly help combat environmental degradation by serving as a barrier against shifting sand dunes and storms.

Additionally, this strategy not only has the potential to provide food, fodder, and fuel but also increases the availability of arable land for growing local populations who currently face challenges due to limited productive land. Integrating this species into agroforestry systems can enhance the productivity of various agricultural activities while protecting soil, water, and livestock resources.

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Review Article

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Economically important underutilized fruits suitable for arid eco-system-A review

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ABSTRACT

The climatic conditions of western Rajasthan and parts of Gujarat are characterized by low and erratic rainfall, high thermal oscillation, and harsh weather. As a result, much of the land is barren, making it suitable for the cultivation of arid fruits that are currently underutilized. Some examples of these underutilized fruits include Kair (*Capparis deciduas L.)*, Karonda (*Carissa carandas L.*), Khejri (*Prosopis cineraria*), Pilu (*Salvadora oleoides*), Tamarind (*Tamarindus indica*), Wood apple (*Feronia limonia L. Swingle*), Cactus pear (*Opuntia ficus-indica*), Nagphani (*Opuntia elatior Mill.*), and Dansara (*Rhus mysorenis* Hene ex Wight & Arn.). These fruit crops grow naturally and have been utilized by local communities for a long time due to their nutritional value and resilience to harsh climatic conditions. This review focuses on the underexploited fruits with the potential to thrive in such environments, discussing aspects such as value addition, post-harvest management, and future prospects for these crops.

Introduction

Biodiversity plays a great role for sustainable livelihoods under arid ecosystem. It encompasses the variability of living organism including their *in situ* and *ex situ* conservation of flora and fauna along with their genetic and ecosystem levels. India is the second leading fruit producing country, sharing 11.2 percent of world's total fruit production. India exports only 1.2 per cent fruits in global market which is very less. Rajasthan is the biggest state of India but its contribution in fruit production is not so significant. The western part of Rajasthan is covered under arid-region where ample opportunities exist for production of arid fruits. Beside this, some part of Gujarat, Haryana, Karnataka and Andhra Pradesh are also covered under arid-region. In these area number of local fruits are grown which are highly nutritious. These fruits are very common in local population but new in national or international community and therefore are called as underutilized fruits (Table 1). Fruits like Kair (*Capparis deciduas* L.), Karonda (*Carissa carandas* L.), Khejiri (*Proso-*

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pis cineraria), Pilu (*Salvadora oleoides*), Tamarind (*Tamarindus indica*), Woodapple (*Feronia limonia* L. Swingle), Cactus pear (*Opuntia ficus-indica*), Dragon fruit (*Hylocereus Spp*.), Nagphani (*Opuntia elatior* Mill.), Dansara (*Rhus mysorenis* Hene ex Wight & Arn.), *etc*. are not under commercial cultivation and therefore, no recommended package of practices are available. These underutilized fruits and their by products are being utilized by the tribal's since long time. Arid fruits are rich in carbohydrates, protein, fat, vitamins A, B and C, minerals (iron, potassium, calcium, *etc*.) and dietary fiber *etc*. In Ayurveda and homeopathy also, the fresh arid fruits or their byproducts are used to control several human diseases. These fruits can be successfully grown on barren land with limited moisture and extreme weather conditions (Gupta *et al.*, 2001). Hence, underutilized arid fruits can help to overcome the malnutrition problem in our country along with better utilization of available barren land.

Table 1. Botanical description and distribution of economical importance fruit tree under arid-ecosystem

S.No.	Common name	Locally name	Botanical name	Family	Chromosome no.	Distribution	References
1	Kair	Kair, Taint	*Capparis decidua* L.	Capparidaceae	x = 7,8	Rajasthan, Gujarat, Punjab, U.P., Punjab, M.P. and Andhra Pradesh	Meghwal and Singh (2016)
2	Karonda	Karunja, Karonda	*Carissa carandas* L.	Apocynaceae	2n=22	Bihar, West Bengal, Uttar Pradesh, Uttarakhand, Maharashtra, Rajasthan and Southern India	Meghwal and Singh (2016)
3	Khejri	Khajri, Jati	*Prosopis cineraria* (L.) Druce	Mimosaceae	2n=2x=28	Rajasthan	Meghwal and Singh (2016)
4	Pilu	Chhatapilu, Jhal, Meetha Jhala	*Salvadora oleoides* Decne	Salvadoraceae	2n=24	Punjab, Haryana, and Gujarat, Madhya Pradesh, Rajasthan and southwestern parts of Utter Pradesh	Laura *et al.* (2014)
5	Tamarind	Imli	*Tamarindus indica* L.	Caesalpiniaceae	2n=24	Tamil Nadu, Karnataka, M.P., Andra Pradesh, Telangana, Gujarat, Rajasthan,	Mani *et al.* (2020)
6	Wood apple	Keth, Kaitha, Elephant apple, Monkey fruit and kathbel	*Feronia limonia* (L.) Swingle	Rutaceae	2n=18	Maharashtra , M.P., Jharkhand, U.P., Chhattisgarh and Rajasthan	Krishna *et al.* (2016)
7	Cactus	Prickly pear	*Opuntia ficus-indica* (L) Mill.	Cactaceae	2n= 22, 44, 66, 88	Rajasthan desert , Bhuj in Gujarat and Western Maharashtra	Kiesling and Metzing (2017) and Kumar *et al.* (2018)
			Opuntia albicarpa	Cactaceae	2n=22,44,66	Rajasthan	Kumar *et al.* (2018)
			Opuntia robusta Wendl.	Cactaceae	2n=22,44,66	Rajasthan	Kumar e*t al.* (2018)
8	Columnar Cacti	Koubo	*Cereus peruvianus* Britton and Rose	Cactaceae	-	Rajasthan	Mizrahi *et al*. (2002)
9	Red flower Prickly pear	Nagphani/ Thapa thor	*Opuntia elatior* Mill.	Cactaceae	-	Rajasthan	Meena (2015)
10	Dansara	Katiya/ Khatuna	*Rhus mysorenis* Hene ex Wight & Arn.	Anacardiaceae	-	Rajasthan, Haryana, Punjab, Andhra Pradesh and Gujarat	Swathi *et al.* (2015)

Economic importance of underutilized arid fruits

Underutilized fruits are rich source of vitamins, minerals, carbohydrates, proteins, and fats. They are also rich in phytochemicals having several medicinal value and can help to prevent and cure diseases like kwashiorkor, marasmus and anemia. These crops are easier to grow than major commercially grown crops and can produce a crop even under adverse soil and climatic conditions. Underutilized arid fruits require low input and can produce higher biomass than field crops per unit area. Cultivation of underutilized arid fruits crops can help to improve wastelands by preventing soil erosion, improving soil fertility, and promoting biodiversity. Further, the underutilized fruits can provide economic security to tribals by providing employment and good returns from their sale. Keeping in view the importance of underutilized arid fruits, their economic importance is described as under and nutritive value is presented in Table 2.

Kair: It is a shrub naturally grown at farm boundaries, barren and wasteland. It occurs in tropical and warm region possessing several economic significance (Vyas *et al.*, 2009). Kair provides vegetative cover, improves soil fertility, check soil erosion and increased biodiversity (Meghwal and Singh, 2016). It is a xerophytic plant with less foliage and deep root system hence, suitable for cultivation on wastelands, especially to combat soil and wind erosions. Tender and fully developed pod are used for making pickle and dried pods for making Panchkuta. Kair plant has several medicinal values and raw material for drug industry as anti-inflammatory, laxative, anti-diabetic, anthelmintic, antibacterial, astringent, digestive, diaphoretic and anodyne.

Karonda: A small bushy tree with sharp spine and evergreen foliage. It is considered as an economic and popular protective live fence plant. It can be grown in wasteland, problematic soil, unproductive land and low moisture conditions. Its fruit is called berry which is a rich source of iron, calcium, magnesium, phosphorus and vitamin C (Bairwa, 2020). Plant produce sufficient amount of fruits and fruits are sour and astringent in taste. It has medicinal uses against bilious, capillary bleeding, cold, influenza, piles, dysentery, habitual constipation and scurvy disease. Efforts are going on to domesticate this fruit and several varieties *viz*., Pant Sudarshan, Pant Manohar and Pant Suvarna have been released from GBPUA&T, Pantnagar, Thar Kamal from CHES (CIAH), Godhra (Singh *et al.*, 2013) and Maru Gaurav from CAZRI, Jodhpur (Meghwal and Singh, 2019). Fruits have nutritive value like rich source of iron, fair amount of vitamin C. However, it has not yet been popularized among national and international farming community.

Khejri: Khejri is a tree which has multipurpose uses. It is a state tree of Rajasthan and also related to very famous Khejarli massacre (Chipko movement) of Rajasthan. The immature pods are edible and rich in crude protein (18%), carbohydrates (56%) and minerals such as phosphorus (0.4%), calcium (0.4%) and iron (0.2%) (Duhan *et al*., 1992). Fruits are used after drying for making special dish "Panchkuta" that is prepared with five different nutritionally rich arid fruits and vegetable (ker, khejri, lasora, kumat and kachri) of western Rajasthan. Arya *et al*. (1991) reported that dried ripe pods contain 9-14% crude protein and 6-16% sugar; it can be powdered and used in bakery industries. Dry leaves of khejri are used as animal feeds. The Central Institute of Arid Horticulture, Bikaner is working on this plant and has developed first variety Thar Shobha by adapting bud grafting technique. Its bark extract is used to overcome the poisonous effects of the scorpion and snake bites.

Pilu: Pilu tree has a great economical and ethno-medicinal value. Ripe fruits are sweet and edible. Its fruits boosted the milk if used as cattle fed. The fresh fruits contain about 70% juice. The method of extraction of juice and preparation of squash and Jam has been standardized (Khan *et al*., 2004). The pulp contains good amount of glucose, fructose, sucrose and calcium (Duhan *et al*., 1992). Fruits have medicinal uses to control enlarged spleen, rheumatism, cough and low fever. Seeds contain fats which are used as remedy of rheumatic pains (Anonymous, 1972). Seeds are rich in fat (40-50%) and its purified oil used in soap, non-edible wax and detergent industries. After extraction of oil the cake is also useful as manure. Plants are woody and hardy in nature, hence used in making furniture and agricultural implements.

Tamarind: Evergreen and partially semi-evergreen, perennial and woody tree species. It is well adopted under harsh climatic conditions (low rainfall, high temperature, frost, *etc.)* but requires sub-tropical and dry condition for better flowering and fruiting. Its pods are considered as fruits which are slightly curved, brownish-ash coloured and contain 1-12 seed per fruit. Pods are rich in antioxidant, anti-inflammatory properties, thus it provides a huge potential for biomedical science (Singh *et al.*, 2020). They are being used by household in making chutney and other recipes (Mani et al., 2020). Different varieties have been released from different Institute viz., DTS-1 and DTS-2 (UAS, Dharwad), PKM-1 (TNAU, Tamil Nadu), Urigam (Department of Horticulture, Tamil Nadu), Pratisthan (Fruit Research Station, Andhra Pradesh), Goma Parteek (CHES, Godhra), Yogeshwari (Taluk seed farm, Ambajogai, Maharashtra). Its leaves are use in herbal medicines; fruits are rich source of antioxidant which is improving immune system in human beings. Fruit pulp is also reducing to serum lipids which overcome the cardiovascular diseases.

Wood apple: It is also known as elephant apple, monkey

fruit and kathbel. It grows naturally in waste and undulate land. Two forms of plants are form one is small with acidic fruit and second is tall with sweetish fruits. Ripe fruit are rich source of riboflavin, vitamin C *etc.* Pulp of the fruit is highly nutritious and use in liver, diarrhea, dysentery and throat problem. It is considered sacred by Hindus and is widely cultivated or naturally grown in India. Fruit pulp, seed and oil has several beneficial effects as liver and cardiac tonic. It has remedial value of bones and joints problem, bilious diseases, prevention of capillary bleeding, cold, influenza, dysentery, piles, habitual constipation and scurvy (Pal *et al*., 2019). A variety Thar Gaurav has been developed by Regional Station CHES, Godhra (CIAH, Bikaner-Rajasthan).

Cactus: Prickly pear belongs to family Cactaceae. Plants are succulent, throne and less foliage, having 122 genera with approximately 1600 species which have spines and exhibit stem succulence. In India, many species of prickly pear are found growing either as wild xerophytes plant in arid and semi-arid regions. Now-a-days, it is parts of kitchen or family gardens in arid and semi-arid areas. Cactus pear has numerous uses. It plays an ecological role in soil conservation as well as producing edible fruits and vegetable (nopalitos) for human consumption, forage for livestock and a number of other value added products. The high sugar and low acid blend of the fruit makes it delicious and palatable. The fruit has a high content of free amino acids, particularly proline and glutamine, the highest level being that of nutraceutical taurine, up to 572.1 mg/L. Traditionally cactus nopal has been beneficial for burns, wounds, edema, hyperlipidemia, obesity and catarrhal gastritis. The edible cactus pear could be considered a new expectation for wasteland development (Singh and Felker, 1995). Fruits are edible and its tender cladodes can be used to prepare salad, vegetable, pickle and also fed as fodder. Use of *Opuntia* in natural landscape and as agricultural crop has been adopted in many countries. The Opuntia *elatior* is use as live fence on the field bunds and it is grown naturally in different parts of Rajasthan. The market for species is extensive, so need to enhance marketing strategies and post-harvest technology in near future.

Nagphani: It is a succulent plant with CAM mechanism of photosynthesis. Plants have deep tap root system. It blooms attractive flower under extreme hot conditions under Thar Desert hence, also included in Prickly pear group. Fruit become reddish to reddish pink when ripe, and used to consumed directly by the tribal people (Meena, 2015). Two to eight spines found in cluster on the stem. The baked fruit is used in whooping cough and also beneficial to the diabetic, prostate problem and dentistry (Kirtikar and Basu, 1999).

Dansara: Hardy shrub plant with thorny branches. It can be grown in rocky and waste lands. It requires less amount of water and grows naturally in Rajasthan. Small brown to blackish shiny fruits are eaten by the children and especially women due to sour and sweet taste (Swathi *et al*., 2015). Leaf paste is used to overcome the rash and allergy in human beings (Umberto, 2012).

Table 2. Bowl of nutrients for the rural community

S.No.	Fruits	Major Nutrients	Quantity
1.	Kair	Protein and vitamin C	8.6 % and 7.8 mg per100 g pulp
2.	Karonda	Iron	39.1 mg per100g
3.	Khejri	Crude protein	12-18%
4.	Pilu	Alburninoides and fibre	18.9% and 5.8%
5.	Tamarind	Vitamin C and Tartaric acid	244 mg and 17.1% per 100 g pulp
6.	Wood apple	Riboflavin	170 mg per 100 g pulp
7.	Prickly pear	Vitamin C	12-81 mg per 100 g pulp

Value-added products : The arid fruit plants bear fruits in specific session and generally spoil within few days of picking due to softness and high pulp content. Storage of harvested fruits for a longer period is a big problem in these areas due to inadequate storage facility like cold storage, zero energy cooling chamber, freezer, *etc*. Hence, uses of post harvest techniques to maintain the fruit quality and reduce post harvest losses are important for livelihood of poor farmers of this region. The traditional and modern post harvest management practices are available to improve the fruit nutritional quality as well as to fulfill the consumer demand during off season. The techniques for preparing these value-added products like pickle, juice, jam, dried fruit, candy, syrup, powders, RTS, *etc*. have been standardized (Table 3). It is imperative that popularization of these value-added products shall help to enlarge the small scale industries and thus give employment to the tribal youth. These products have already caught the national and international market can share significantly in agriculture GDP in near future.

Table 3. Standardized value-added product of economical importance fruit tree under arid-ecosystem

S.No.	Fruits	Value-added products	References
1	Kair	Pickle, Panchkuta and dried fruits	Rawat and Das, 2020
2	Karonda	Pickle, Candy, Jelly, Jam, Preserve, Wine and Chutney	Singh *et al*., 2020
3	Khejri	Pickle, Panchkuta and dried fruits	Singh *et al*., 2020
4	Pilu	RTS, Nectar, Wine and dried fruits	Krishna *et al*., 2019
5	Tamarind	Tokku, Jelloe, Toffees, Sauce, Pickle, Juice concentrate, Pulp powder, Jam, Syrup, Candy and Kernel powder.	Mani *et al*., 2020; Singh *et al*., 2020
6	Wood apple	Squash, Powder, sherbet, Pickle, Chutney, Fruit bar and Feronia gum	Pandy *et al*., 2014; Yadav, 2018
7	Prickly pear	Squash, pickle, ready to serve drinks, colour from fruit and cochineal, cladodes for culinary and salad	FAO, 2013; Corrales and Flores, 2003

Conclusion

Underutilized fruits in arid regions hold significant potential but have remained neglected due to insufficient research and a lack of awareness regarding their nutritional and medicinal values. Genetic resources for these fruits are still present in farmers' fields, highlighting the need for standardized propagation techniques and the development of improved varieties. By focusing on these aspects, these fruits could significantly enhance the income of rural communities through processing, packaging, and value addition. However, to fully realize their potential, increased awareness and effective marketing strategies are essential.

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Review Article

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Present status and future prospects of Ber (*Ziziphus mauritiana* Lamk.)-A review

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ABSTRACT

Ber (*Ziziphus mauritiana* Lamk.) is one of the hardy fruits that can be profitably cultivated in arid and semi-arid conditions, where most other fruit trees fail to grow due to lack of irrigation and other environmental constraints. It is mainly cultivated for its fresh fruits and rightly called as poor man's apple due to its high nutritional value *i.e.* higher protein (0.8 g), β-carotene (70 IU), vitamin C (50-100 mg) and medicinal value. In North India, ber flowers in the month of August-September. It mainly produces heavy flowers in the auxiliary cymes on maturation, and current season's growth with very high fruit set percentage. It can be processed to prepare various value added products *i.e.* murabba, pulps, jam, candies and beverage. The best method of commercial propagation is by budding and the widely adopted is shield budding (T or I budding). Recently success in micro propagation of ber has also been achieved and the best explant for *in vitro* micro propagation is stem from mature tree. Due to its ability to withstand adverse climatic conditions, it is truly a "desert apple" or "king of arid fruits" and can be profitable grown by farmers of arid and semi-arid regions of India.

Introduction

The ber (*Zizyphus mauritiana*) belonging to the buckthorn family Rhamnaceae and is also called as jujube (Singh *et al.*, 2007). It is mostly grown in semi-arid regions of tropical and sub-tropical parts of India. It is the only fruit tree which is profitably grown by Indian farmers under dry land conditions. Apart from India it is mainly also grown in some countries of central Asia *i.e.* China and Taiwan. The fruit has religious association with Indian culture since ancient times. The fruit tree is hardy and adapts and thrives well in areas with poor water availability, inferior soil and adverse climatic conditions (Krishna *et al.*, 2014). It is believed to have originated in India and is regarded as the king of arid fruits; it has also earning the title of poor man's apple due to its high nutritive value. Ber is a seasonal fruit which can be made available throughout the year with different food products with extended shelf life. The tree suits well in areas with poor soil fertility and management where most other fruit trees fail to establish them or significant yield losses occurs (Dalal *et al.*, 2019). In India three main species are found and among

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them *Z. mauritiana* is mainly grown and has high economic importance with several varieties been released in the country. India is the largest producer of ber. It is found growing wild, semi wild and also in cultivated in almost all parts of the country. The area under cultivation in India is 8.7 lakh ha with an annual production of 8.9 lakh tones (Bolada *et al.*, 2012). Indian Ber (jujube) have varieties known for their taste, nutrition and higher yields. The varieties like Umran, Karaka, Gola, Seb, Chhuhara, Sanaur-2, Ilaichi and Mehrun are the most promising varieties of ber in India (Azam-Ali *et al.*, 2001). Fruits are mostly seasonal and are highly perishable. It is estimated that the total spoilage of fruits in India due to post-harvest losses is around 20- 30 % (Madan and Ullasa, 1993). Lack of adequate processing facilities, transportation and storage are the main bottleneck leading to loss of valuable produce. The quality of fruit is best under hot, sunny and dry conditions, but for optimum growth and flowering and maturity there should be availability of moisture in the soil. Ber is known for its ability to withstand adverse climatic conditions and shows a good level of resistance against salinity, drought and water logging. The tree frequently faces desiccation damage due to high rate of cuticular transpiration, which usually associated with high fatty acids and low aldehydes and alcohol content in the waxy cuticle (Dalal *et al.*, 2019). The major growing states in India are Madhya Pradesh, Bihar, Uttar Pradesh, Punjab, Haryana, Rajasthan, Gujarat, Maharashtra and Andhra Pradesh. The area under ber has increased from 42,000 Ha to 49,000 Ha from 2014-15 to 2016-17 resulting in an increase in production from 401,000 MT to 481,000 MT during the same time period. The present work thus focuses on the importance of ber and as an important means to increase farmer's income of the in rainfed/dry land conditions.

Botanic description

The Indian ber is an evergreen shrub or tree with a spreading canopy and vine-like branches, the leaves have and dark green appearance on the upper surface with fine tooth at margin (Pareek *et al.*, 2007). The height of the tree may reach up to 15 m high, with a trunk diameter of 40 cm or more. It bears stipular spines and many drooping branches. The tree has a well-developed tap root system which helps in its establishment. It flowers in autumn, bears fruits at the end of winter. It sheds leaves during hot weather after fruiting and does not withstand cold conditions. The inflorescence is cymose with 15-28 flowers per cyme (Singh and Sharma, 2020). The tree bears are pale white pentamarous flowers with stamens attached to petals. At the time of anthesis the stigma becomes receptive for a period of 12 hrs, the time available for cross pollination to occur. Flies belonging to the genus *Physiophora* are the main pollinator at the time of anthesis. The varieties are mostly self-compatible, but poor fruit set sometime occurs due to lack of insect pollinators. Plant growth regulators (PGRS) play an important role in regulation of different physiological process, growth, yield and quality of fruit crops (Suman *et al.*, 2017). Application of phytohormones especially GA and NAA at a concentration of 10-50 ppm is found to be effective in increasing the fruit set. The fruit is a berry and bears a single stone, the shape of fruit generally varies from round to oblong or oval in shape. The fruit skin is thin and may be smooth or rough with glossy appearance. They are first green and turn yellow as they ripen. At full maturity the fruit are red, juicy and soft and has a pleasant aroma and sweet taste (Pareek *et al.*, 2007). The fruit may be round, flat, obliquely beaked, pointed or bluntly tapering at the styler end whereas the stem end may be grooved or smooth depending on the cultivar. Weight of the fruit generally varies from 20 to 50 g.

Nutritive and medicinal value

The ber berry is highly nutritious, although, called as poor man's fruit; the nutritional value is at par with many other fruits (Panwar, 2012). The fresh fruit contains 13 to 20 % TSS and 0.2 to 1.0 % acidity. The fruit per 100 g contains energy 24.76 kJ (5.92 kcal), carbohydrates 17 g, sugars 5.4-10.5 g, dietary fiber 0.60 g, fat 0.07 g, protein 0.8 g; vitamins like Thiamine (B_1) 0.022 mg, Riboflavin (B_2) 0.029 mg, Niacin (B_3) 0.78 mg, other vitamins like vitamin C 120 mg, β-carotene (Vit. A) 80 µg; minerals like Calcium 25.6 mg, Iron 1.1 mg, Phosphorus 26.8 mg, Other constituents Water 81.6-83.0 g (Kavitha *et al.*, 2014). The fruits are generally eaten fresh and may also be eaten dried or candied. It may even be processed to prepare murabba, pulps, jam, candy, chutney, squash or nectar prepared from the pulp can also be served as beverages. The fruits of wild varieties particularly malahber (*Z. numularia*) are sun dried and are often sold during off season. Ber trees are often used for rearing lac insects, the leaves along with tender shoots are used as fodder and wood used as fuel. The tree also has different medicinal uses and parts like root, bark, leaves, flowers, seeds, *etc.* are used in ayurvedic and yunani system of medicines for treatment of ailments like diarrhoea, cough, ulcer, indigestion, headache, bleeding gums, asthma, *etc.* (Dalal *et al.*, 2019). It also acts as a blood purifier and appetizer.

Crop improvement

a. Genetic diversity: The center of origin of *Zizyphus mauntiana* is India, while of *Zizyphus vulgaria* is China. More than 600 species belonging to the genus *Zizyphus* are known out of which 18-20 are native to India. They are found throughout the country *viz*., *Z. apetala*, *Z. funiculosa* and *Z. incurve* are native to north eastern hills, *Z. mauritiana* and *Z. nummularia* found particularly in North Western India including U.P, *Z. oenoplia and Z. rugosa* in central and east-

ern India, *Z. Vulgaris* grows naturally in the North Western Himalayas, *Z. rupicola* is found in central and Eastern India and *Z. xylocarpus* in M.P. and Peninsular region as reported by (Pareek, 1988). Among all ber species *Z. mauritiana* is the most important fruit species and is widely cultivated in the tropical and subtropical regions of India (Singh *et al.*, 2007). Fruits of *Z. nummularia* and *Z. rotundifolia* are also edible and the *Z. rotundifolia* is used as rootstock.

b. Germplasm conservation: A lot of research work for improvement in the yield and quality of fruits is being done by different institutions across the country (Kalinganire *et al.*, 2012). Several germplasm including species and cultivars have also been collected and are being maintained in the field gene banks of CIAH, Bikaner; and NBPGR, Jodhpur; IAPKV, Rahuri; CCSHAU, Hisar; CAZRI, Jodhpur. CIAH, Bikaner has highest collections (338) of these and had been made available in the National Field Repository of ber (Bolada *et al.*, 2012).

c. Improvement approach: In India a large number of ber cultivars are cultivated and attempts have been made to identify superior cultivars based on their vegetative and fruit characteristics. As ber is naturally cross pollinated, it gives rise to natural hybrids having wide genetic bases. This is further augmented by high levels polyploidy in fruiting tree, which helps in creating large genetic variability. Attempts have been made by different institutions across the country for improvement of cultivars utilizing modern techniques including micro propagation.

d. Variety improvement: Varietal improvement programs have been under taken by different research institutions across India to develop superior high yielding varieties suitable for commercial cultivation. CAZRI, Jodhpur has a fair share in its efforts to develop superior ber cultivars; they evaluated more than 80 cultivars under varying rainfall conditions (150-500 mm). Cultivars with early ripening characteristics *i.e.* Seb, Gola and Mundia are recommended for low average rainfall (150 mm) regions. Late ripening cultivars are not suitable for rainfed areas having average rainfall less than 500 mm. some of the popular ber varieties are as under:

Goma Kirti: It is a high yielding and early maturing variety, which fetches good price in the market. It is resistant to various diseases and pests by virtue of its earliness.

Thar Sevika: It is a F_1 hybrid between Seb and Katha. Thar Sevika is an early maturing variety. The fruits are juicy, sweet with TSS content of 22-24%. Fruits after consumption do not cause throat soaring, which is common in other cultivars. Average fruit yield is 30-32 kg/tree. The hybrid is also suitable for staggered picking which can be done upto third week of January. It is developed by CIAH, Bikaner.

Thar Bhubhraj: It is a selection from local material of Bhusavar area of Bharatpur district of Rajasthan.

Gola: It is an early maturing variety, mainly grown in Delhi, Haryana and other adjoining areas. It bears medium sized round to oval excellent quality fruits which are greenish to golden yellow in colour at the time of ripening. The average fruit weight varies from 15-20 g and it yields up to 85 kg/tree.

Seb: It is an early maturing variety which bears round fruits, resembling crab-apple. Fruits are light pinkish yellow in colour with slightly rough skin and occasional specks at maturity. It yields up to 85 kg/tree.

Selected Safeda: This early maturing variety is popularly grown in Haryana and Punjab. It is resistant to powdery mildew disease. The fruit is medium sized and almost round in shape. The ripened fruits are sweet, fleshy and develop golden yellow to greenish yellow colouration at the time of ripening. The average fruit weight varies from 25-30 g.

Kaithli: It is a mid-season variety and is mainly grown in Punjab and Haryana. The fruit is medium in size and oval to oblong in shape. The fruit develops greenish yellow to golden yellow color on ripening. Mature fruits are thin skinned and sweet in taste. The fruit weight varies from 25-30 g and yields up to 125 kg/tree.

Sannaur: It is a mid-season variety and is mainly grown in Punjab and Haryana. The fruits are medium sized and oval to ovate in shape. The variety is resistant to powdery mildew. The average weight of the fruit varies from 25-30 g and it yields up to 100 kg/tree.

Meharun: It is a mid-season variety and is mainly grown in Gujarat. The variety is resistant to fruit flies. The fruits are medium sized and oval to ovate in shape. The fruit develops light yellow to greenish yellow colouration upon ripening. The average weight of fruit varies from 20-25 g.

Banarasi Kadaka: It is a very popular mid-season variety grown in Uttar Pradesh. The fruit are large in size and oblong in shape. The fruit develops yellow coloration upon maturity. The average weight of fruit varies from 40-50 g and it yields up to 125 kg/tree.

Umran: It is a late season variety mainly grown in Punjab and Haryana. The fruits are oval to elliptical in shape and large in size. The fruits develops golden yellow color on ripening. It is a high yielding variety with appreciable keeping quality. The fruits can be transported to long distances without significant damage and spoilage. It is also resistant to fruit flies. The weight of the fruit varies from 35-40 g and it yields up to 200 kg/tree.

Soil and climate

It is a very hardy fruit tree and performs well under adverse climate and poor soil conditions. It can be successfully grown in tropical and sub-tropical climate. The ber is peculiar for its ability to grow on wide range of soils (Bohane *et al.*, 2016). Deep sandy to sandy loams are best suited for ber cultivation. It can be grown up to a height of 100 m above sea level. Plants can tolerate soil salinity (pH > 9) and water salinity up to a limited extent. Ber can be grown satisfactorily in alkali soils characterized by high pH and sodicity. Application of gypsum @ 5 kg/ pit followed by flooding about one week prior to planting is recommended in such soils. Ber is highly drought tolerant fruit tree and can withstand to extremely high temperatures. Normally it prefers drier climate for good quality fruiting but can also be grown under tropical and subtropical regions of the country. Some of the ber species are also found in the foot hills of temperate regions. However temperature below freezing point is injurious to young plants as well as fruits. Areas receiving annual rainfall in the range of 400-650 mm are well suited for its cultivation.

Propagation

In ber T-budding is generally practiced at a height of 15 cm above the ground level during June to September. Lower most shoots/ sprouts emerging on the rootstock below the bud are to be removed frequently after budding. 50% of the tops may also be looped before removal of whole top above the union points after one month of budding. Successful buds should be single stemmed soon after the sprouting.

Cuttings: Treatment of green wood cuttings of Indian jujube or ber with 250- 500 ppm IBA, 250-500 ppm NAA results in 85 % rooting in sand and has a high percentage of survival (Shen *et al.*, 1992).

Budding: It is known to be the best method of ber propagation. Different type of budding techniques *i.e.* budding, ring, patch and forkert budding *etc*. (Pareek, 1978) have been used, but the best and widely accepted of budding is shield budding (T or I budding). The ring budding is cumbersome, as there is requirement of equal thickness of stock and scion for successful unions. The most widely used rootstock used in budding is *Z. rotundifolia* also known as Bordi. Slow growing rootstock *i.e. Z. nummularia* if used generally leads to incompatibility issues. The time of budding mainly depends on climatic variables *viz*., temperature, humidity and availability of budding material. There are chances of breaking of bud union if wind velocity is high. Therefore the best time for budding especially in Western Rajasthan is in the month of July (Pareek, 1983). Although an initial investment is very high but a net profit can be earned from ber nurseries provided there is guaranteed sale of plants at a reasonable price of Rs. 10 per budling (Singh *et al.*, 2004). Cultivars like ` Elaichi and `Gola' showed best compatibility with the local rootstocks and resulted in 100 % success with maximum in budling growth while Banarasi Karaka' gave lowest of 70% (Ghosh, 2009). The budded scion of Banarasi Karaka performs best in open conditions rather than shade. The month of May, June and September are best for *in situ* budding as cent percent success with maximum plant growth have been observed, while in the months of May and June a success rate of 75 to 85 % was observed.

Rootstocks: Stock and scion compatibility studies were carried in ber cultivars *viz*., Banarasi Karaka, Ponda and Gola with 3 rootstocks *viz*., Jhar ber (*Zizyphus nummularia*), (*Zizyphus mauritiana* ecotype-29) and (*Zizyphus mauritiana* ecotype-Assam Gauhati). The rootstock Jhar ber showed incompatibility with inverted bottleneck symptoms: budded with Gola cultivar. All other combinations were compatible with perfect unions. The histological studies of incompatibility showed that it is mainly due to absence of callus production between the rootstock and scion resulting into a wide gap and weak and unhealthy plants (Verma *et al.*, 2000). In another study *Zizyphus mauritiana* cv. Umran was budded on 12 rootstocks *i.e.* Five *Z. mauritiana* accessions obtained from different parts of India, Chinese. *Z. jujuba*, Argentinian *Z. zoaziroo*, Indian *Z. xylopyrus* and four accessions of *Zizyphus nummularia* from different regions of India (Bal *et al.*, 1997). Umran on *Zizyphus mauritiana* rootstock showed most vigorous growth and produced the highest cumulative fruit yield of 115-146 kg/ tree.

Raising of seedlings: Nursery seedling may be produced by soaking seeds for about 24 hrs in water, it promotes early and higher germination along with good vegetative growth in comparison with sowing of whole seeds (Mankar *et al.*, 1997). Cracked seeds also exhibit good germination, but germination percentage not at par with water soaking treatment. Conventional method *i.e.* budding usually takes about 13 months to raise plant, suitable for planting in orchards. High mortality while planting usually occurs in the field due to damage to the tap roots.

Seedlings may be raised *in situ*, but to cater damage while planting it's better to raise them in polythene bags. Seedling raised in polythene bags are budded and there after transplanted in the desired place. 90 days old seedlings are budded in July and they are ready for planting a month earlier.

Micro propagation: Different types of explants have been examined under *in vitro* condition to evaluate factors influencing regeneration of juvenile explants and callus of different species of ber. For leaf and cotyledon explants of *Z. mauritiana* and *Z. nummularia*, root and hypocotyl callus regenerated with relatively high concentrations of NAA and BA (2.5 and 0.6 ppm, respectively). High number of shoots from explants of both *Z. mauritiana* and *Z. nummularia* was observed on medium containing nitrate N at a concentration of 526.6 ppm. Singh *et al.* (2010) found that shoot tip explant was better than nodal and inter nodal explants. BAP (2.0 ppm), NAA (0.1 ppm) and GA, (0.1 ppm) were found to be best for shoot proliferation considering higher sprouting percentage, number of shoots, shoot length and leaf area in medium supplemented with these PGRs. For root induction percent, root regeneration, days to root initiation, root number and root length, medium supplemented with IBA (2.0 ppm) was found to be most effective.

Explants from stem of *Z. mauritiana* obtained from mature tree was best suited and rooting was induced by pretreatment with 50 µM IBA or 50 µM NAA for 24 hours, followed by transference to auxin-free White medium. The plantlets developed grew well in a soil and vermiculite mixture (Mathur *et al.,* 1995). Explants from inter nodal and nodal segments are most responsive on the medium containing zeatin followed by BA (Nisha & Srivastava, 1996). Leaf explants showed high callusing on medium supplemented with 0.25 ppm IBA and 2.5 ppm BA (Fougat *et al.,* 1997). For shoot tips, shoot growth and number of nodes decreased, while branching percentage increased with increasing concentration of BA (Sudhersan *et al.,* 2001). Buds of the small-fruited cultivar of *Z. jujuba* shows higher shooting percentage than medium and large-fruited cultivars. The best results were obtained in modified Pierik nutrient medium, with low BA and IBA concentrations. Cold treatment for 30 days in darkness facilitated embryo development and plant growth (Assareh and Sardabi, 2005). For shoot tips, the best results were observed on medium containing 2.0 ppm IBA or 0.05 ppm IAA + 1.0 ppm IBA. Temperature dependence of rooting with a rooting percentage of 99–100%, under a 12-hour photoperiod has been observed by Du *et al.* (1997).

A micro propagation protocol for *Z. spina-christi* has been developed by Sudhersan and Hussain (2003). It includes three distinct culture phases *i.e.* initiation and multiplication, shoot growth and elongation and root formation. Initiation and multiplication medium contained 0.1–1.0 ppm BA, Growth and elongation medium did not contain any plant growth regulator (PGR) while the rooting medium contained 10 ppm IBA. About 300 explants were obtained from a single shoot tip by the end of the three subcultures.

Planting: Monsoon season (July-September) is best time for planting of ber. In India plantation is done in square system, at a spacing of 6 x 6 m in low rainfall areas and 7 x 8 m and 8 x 8 m in the irrigated regions or in those receiving higher rainfall. In rain fed areas, shaping the interspaces between tree rows to provide 5% slope towards the plant helps accumulate run-off water during monsoon results in higher plant establishment and profuse vegetative growth. In irrigated areas (Punjab and Haryana), ber plants can also be transplanted from January–March also. In sandy soils, placing sub-surface barriers of bentonite clay reduces infiltration of water and thus increases success of plantation.

Irrigation: In rain fed areas water conservation is an important aspect of ber cultivation, arrangement for *in-situ* water harvesting should be done in the orchards by giving 5% slope to the inter-row spaces towards the trees. Ber plants have well developed deep tap root system and have xerophytic nature and once established, needs little care and irrigation. The harvesting of fruits is over by April and plants become dormant in May-June and shed their leaves. Ber trees need irrigation from November to February for better fruit development. They do not need irrigation during the fruit maturation. Black polythene mulch helps conserve soil moisture and improves growth of the trees. Irrigation during November-February at 3 to 4 weeks interval is done in irrigated areas of Punjab and Haryana, but irrigation during October causes significant flower shedding and during March-April causes fruit spoilage and delayed ripening.

Training and pruning: During the first 2 to 3 years after planting, ber trees should be trained to develop a strong framework. Old growth is removed during March keeping 1–2 nodes above the graft union to induce vigorous new growth. One upright growing vigorous shoot is retained to develop into main trunk which is kept clean of secondary branches up to a height of 30 cm from the ground level. On the main trunk, 3 or 4 well-spaced and favorably located main branches are allowed above when it is headed back. During the second year, these main branches are also clipped retaining 3 to 4 secondary branches on each one of them. This process is continued to develop tertiary branches. Upward growing shoots are retained at each stage to develop an upright tree stature. Not more than one upright growing shoot is retained at a node so that narrow crotches are avoided. This basic frame of the tree is maintained by removing of water sprouts as and when they emerge. Correction in the framework is done at the time of annual pruning. Ber bears fruits on new growth at the axil of the leaves. Therefore, to get optimum growth and yield regular training pruning is essen-

tial. The pruning should be done after 15th May as it improves growth of the tree and fruit quality. If left unpruned the ber trees becomes unproductive and laggy. It has been seen that un-pruned trees may have 10 meter long scaffolds and very little foliage and bear fruit at the tops only. It is essential to remove about 30 percent of the growth of the preceding years. The intensity of pruning in irrigated orchards improves fruit quality as observed by Bisla *et al.* (1991). Singh *et al.* (2004) observed appreciably higher fruit yield from plants pruned on 15th April and mean average yield was 180.3 kg per tree in cv. Sanaur 2. The ber trees are deciduous and are in dormancy stage during May and June and level of reserve metabolites such as carbohydrates, starch and sugars is higher during this phase of dormancy. Pruning during this period can lead to more growth, higher fruit set, and greater yield. Delay in the time of pruning results in lower yield and poor quality fruits, but severely pruned fruit trees produces significantly lower fruit yields than the light pruned plants (Kumar *et al.*, 2002).

Manuring and fertilization: In ber orchards productivity of trees can be improved if manuring is done every year. The dose varies with fertility status of different locations. A dose of 750g N/tree gives highest yield, whereas 250 g N and 250 g P_2O_5 significantly increases fruit yield. Higher plant height, spread, trunk girth, fruit set and fruit retention was recorded with the soil application of recommended FYM + 100% NPK +Azotobacter + PSB in comparison to recommended FYM+ 75% NPK + Azotobacter + PSB (Mahendra *et al.*, 2009). The maximum improvement in soil nutrient status *viz*., organic carbon, N, P. K, Ca, Mg and minimum soil pH and EC was observed with soil application of FYM + 100% NPK + Azotobacter + PSB which was at par with recommended dose of FYM + 75% NPK + Azotobacter + PSB treatment. The nitrogen content is significantly influenced with the application of N in orchard soil (Haridayal *et al.*, 2010). The yield of ber significantly increases with the application of N, P and Zn sulfate.

Weed control: In fruit orchards, weeds are a major hindrance as they starve fruit plants from nutrition, moisture and light. These weeds can be managed by following different strategies, *viz*., chemical, mechanical, manual, mulching and biological methods *etc*. Although chemical weed control as a method for weed management is highly effective and easy, it has its own constraints *viz*., crop injury, soil and water residues, human health apprehension and development of resistance to herbicides (Pot *et al.*, 2011). Manual weed management in present scenario is very expensive and labor intensive. Mechanical weed control is an effective means for short term weed management however in well-established orchards it is quite difficult and less efficient owing to spreading tree canopies as well as limited coverage by agricultural equipment and high chances of potential damage to root and shoots of fruit trees. Shallow ploughing results in less harm to the tree roots, the tillage of orchard floor using rotavator also gives good results. Presently most of the fruit growers rely mainly upon mechanical weed management using adjustable rotavators as this machine not only performs shallow ploughing but also has wider coverage under tree canopies. Covering the soil surface with mulches in the orchards is a safer method as compared to herbicide application (Ramakrishna *et al.*, 2006). Organic mulches are easily available and are cheap in comparison to plastic mulches, which are costly for weed management in orchards. Moreover organic mulches are beneficial for optimum plant growth and yield and improve quality of fruits in addition to being a highly effective method for weed control. Most of the weeds remain under check in summers, due dormant nature of the ber tree. However, perennial weeds like baru grass, dubh grass, parthenium and puthkanda, *etc*. causes substantial problem during growing period of trees. Diuron, Glyphosate and Paraquat at 3-4 kg/ha significantly decreased weed population in ber orchard and increased fruit yields (Bajwa *et al.*, 1993). To control perennial weeds spray of Round Up (glyphosate) @ 10 ml/ litre or Gramoxone @ 6 ml/ litre when the weeds have attained sufficient vegetative growth (20-30 cm height) has been recommended.

Intercropping: The interspace between the rows of fruit trees in ber orchards can be utilized for growing intercrops as after planting of ber plants 4 to 5 years are generally required to cover the interspace between the trees. Leguminous crops are preferably the best choice and are taken as intercrops in ber orchards as they enrich the soil in addition to income generation during the period of orchard establishment. Inter cropping in ber plantation on results in higher yield and monetary return, if chosen wisely. Irrespective of the intercrops, ber based intercropping system recorded a 7.0 % higher ber fruit yield than. Similarly, ber based intercropping system recorded 19.6 % more ber fruit equivalent yield than sole ber system (Patel *et al.*, 2003). Among the different systems evaluated ber+green gram gave the highest net monetary return (Rs. 13099/- ha) followed by ber+sorghum system (Rs. 11,886/-ha). Intercropping in ber recorded on an average 10.0 % higher monetary returns (Rs. 11329/ ha) over ber sole system (Rs. 10287/- ha) per annum. Singh, 1997 reported that initial fruit yield in the intercropped ber orchard increased up to 3 times (14.8 kg/ tree) compared with the control (5.2 kg/ tree). Intercropping in newly planted ber orchard had no adverse effects on plant growth for up to 5 years. Ber + cluster bean-mustard is a compatible combination with respect to sustainable yield, optimum returns, multiple outputs and improvement of site conditions (Saroj *et al.*, 2003)

Rejuvenation of old orchards: It has been observed that engineering of tree architecture, canopy density and photosynthetic efficiency play an important role in governing

the fruiting potential in fruit trees (Lal and Mishra, 2008). Several reports on rejuvenation by pruning, canopy management, dehorning and top working are available in different fruit crops *i.e.* mango, guava, aonla, litchi, peach, apple and ber. The morphological attributes of fruits obtained from rejuvenated trees in ber orchards was significantly better than fruits obtained from non-rejuvenated trees. Singh *et al.* (2015) while studying rejuvenation in Umran, Gola and Seb cultivars of ber found that fruit weight, fruit length, stone length, pulp content and pulp : stone ratio were higher in cv. Umran followed by Gola and Seb, whereas, fruit and stone diameter and stone weight was higher in cv. Gola. Variation in physical parameters of fruits obtained from rejuvenated trees of different cultivars may only be due to their genetic characters. The chemical attributes *i.e.* TSS, TSS : acid ratio and total sugars was slightly higher in fruits from non-rejuvenated trees in each cultivar but the differences were non-significant. However, ascorbic acid content was higher in fruits obtained from rejuvenated trees. The TSS and TSS: acid ratio was higher in cv. Seb, whereas, acidity, total sugars and ascorbic acid contents were found higher in cv. Gola. The technology helps in maintaining the manageable tree height with open architecture and canopy of healthy shoots with outwardly growth facilitating maximum light penetration and its utilization by the plant. Growth of new healthy shoots and luxuriant leaves tend to exhibit high photosynthetic efficiency thereby, keeping a balance between vegetative and reproductive growth which ultimately might increase tree canopy volume, yield and quality of fruits in rejuvenated trees.

Flowering, floral biology and fruit set: The flowering period of ber varies from early June to late November in different cultivars under different agroclimatic conditions. Flowers are borne in the axil of leaves of mature as well as current seasons shoots. The life of individual flower in an inflorescence is very short and many flowers remain unpollinated during their receptive periods. Flowering usually occurs about 21 days from early bud development and length of flowering ranged from 57 to 75 days, depending on cultivar. The mode and time of anthesis is also cultivar specific and may be influenced by environment. Anther dehiscences start about 2 hrs after anthesis and continue for about 2 to 4 hrs. High pollen viability has also been reported in different ber cultivars. Stigma shows peak receptivity at the time of opening of the flower.

Fruit growth and development: Physical and biochemical changes occurring in growth and development of ber fruits have been extensive investigated. Ber fruits follow a double sigmoid growth curve. Fruits are ready for harvest, when having a specific gravity of <1; organolpetic tests also assists in judging maturity of the fruit. Fruit drop also occurs due to lack of fertilization (Singh *et al.*, 2005), to maintain a crop load the tree can sustain (Vashishtha and Pareek, 1979), soil moisture stress, frost, high and low temperature. Fruit set increases with the application of IAA @ 100 ppm IAA also removes cross incompatibility problems in ber and IAA treatment also results in increased fruit retention and decreased fruit drop in ber.

Pests: Butani (1979) recorded 80 insect species feeding on ber trees in India. Lakra and Singh (1983) opined that commercial cultivation of ber has become difficult due to attack by more than 100 species of insect pests in north India. Although ber is infested by a large no of insects, yet only few species have attained the status of the pest and cause substantial damage to ber some of the important pests are as under:

Fruit flies (*Carpomyia vesuviana*, *Dacus correctus* and *D. dorsalis*)**:** Among these *C. vesuviana* causes as much as 80% damage to the fruits, under severe. It is the most serious pest of ber. Infestation starts with the onset of fruit setting. The adult female lays eggs singly by inserting its ovipositor into the young developing fruit. The larvae on hatching after 2 to 5 days, start feeding on the pulp and make galleries in it. The excreta of the larva accumulate in the galleries, which may result in rotting of the fruits. Infested fruits become deformed and their growth gets arrested. A large number of such fruits drop off from the trees causing significant reduction in the yield. To prevent infestation, prophylactic sprays may be carried out with 0.03 % oxydemeton or dimethoate starting from the stage when 70-80 % fruits attain pea size and then repeating the spray at one month intervals (Pareek and Nath, 1996). During the maturity of fruits, if necessary, spray with 0.5% Malathion+0.05% sugar solution at weekly intervals.

Fruit borer (*Meridarchis scyrodes*)**:** Damage by larvae of the fruit borer has been observed mainly in southern and western India (Pareek and Nath, 1996). The reddish larvae bore into the fruit and feed on the pulp and accumulate faecal frass within. The moths are small, dark brownish in colour. Pest incidence shows positive correlation with temperature while negative relationship of the incidence of the pests was found with relative humidity, wind speed and cloud cover (Nandihalli *et al.*, 1996). Collection and destruction of fallen fruits and digging the orchard soil under the tree canopy have also given good results. Chemical control consists of first spray at pea stage with monocrotophos (0.03%), second spray after 15 days with fenthion (0.05%) and a third spray 15 days after the second spray with 0.01% carbaryl has been recommended (Pareek and Nath, 1996).

Bark eating caterpillar (*Indarbela quadrinotata*, *I. watsoni* and *I. tetraonis*)**:** The caterpillars have been reported

to make winding galleries of frassy web on the stem near the forks and angles of branches. The caterpillar is hidden in the stem in the day-time and becomes active at night, eating the bark. Heavy infestation by this pest stunts the trees and adversely affects fruit yield. Frassy galleries caused by the pest needs to be removed and cleaned. Then 0.05% monocrotophos is painted on the bark, followed by 0.2% trichlophos and 0.05% chlorfenvinphos (Verma and Singh, 1975). Application of the solution, made up by mixing one litre of kerosene and 100 g soap in 9 L of water, to the holes has been found to effectively control the bark eating caterpillar. Alternatively, each hole should be filled with a solution of 2 ml monocrotophos or 20 ml trichlorphon 50 EC or 30 ml endosulfan 35 EC in 10 L of water and then the holes closed with mud (Azam-Ali *et al.*, 2006).

Hairy caterpillars (*Dasychira mendosa*, *Euproctis fraterna*, *Thiacidas postica*)**:** Hairy caterpillars feed on the young leaves and fruits. The older caterpillars spread in all directions and devour leaves and fruits and sometimes even tender shoots. They start eating new foliage as it grows after pruning and this is continued by overlapping generations. BHC 10% can be dusted to control caterpillars in the young stages. All the instars can be controlled by treatment with 0.1% carbaryl or endosulfan or trichlorphon or 0.05% methyl parathion (Verma *et al.*, 1972). A spray of 0.05% monocrotophos and 0.2% carbaryl (Killex carbaryl 50 WP) is most effective in controlling the pest (Pareek and Nath, 1996).

Diseases

Ber is affected by many serious diseases like powdery mildew, sooty mold, leaf spots (*Alternaria, Cercospora, Septoria, Cladosporium, Pestalotiopsis*, *etc*.) and rust among the fungal infections and witches broom caused by MLOs. Powdery mildew (*Oidium erysiphoides* var. *zizyphi*) is an economically important disease of ber, which results in 50-60% loss in fruit yield and reduces market value of the produce. The disease is known to be severe in early pruned crop (April first fortnight) and is generally favoured by rainfall, warm humid conditions proceeding to its appearance on fruits during September to December. The disease can be effectively managed by alternate sprays of triadimefon at 0.1% followed by wettable sulphur at 0.3% at an interval of 12-15 days. Among many genotypes, Jogia and Mundia were found resistant while, popular cultivar Umran was highly susceptible and another cultivar Kadaka was moderately resistant to powdery mildew. Among the other diseases, sooty mold caused by *Isariopsis inidica* var. *zizyphi* causes sooty/black spots on leaf surface covering large area of leaves, often resulting in defoliation and reduced yields. The leaf spots caused by *Cercospora zizyphi* and *C. jujube* cause circular oval spots on leaves whereas *Alternaria chartarum* forms small irregular brown spots resulting in defoliation. These diseases can be managed by carbendazim at 0.2% spray. The rust (*Phakopsora zizyphi-vulgaris* Diet.) causes small irregular reddish brown pustules covering entire leaves resulting in drying and defoliation. The disease can be managed by spraying mancozeb at 0.2% or zineb at 0.2% or wettable sulphur at 0.2%. Witches broom, a MLO disease causes phyllody of plants producing auxillary bud proliferation giving bushy appearance and transmitted through grafting.

Harvesting and yield: Harvesting of fruits at proper stage of maturity is of much important both for maintaining quality and marketing. Ripening of fruit may take place either before or after harvest, but it is generally accepted that post-harvest ripening of ber only occurs if the fruit is sufficiently mature when picked. Immature fruits do not have desired sweetness and taste, over mature fruits on the other hand loses attractiveness and crispiness and become slimy in texture within a very short span (Pareek, 2001). Fruit colour, percentage of titrable acids and total soluble solids are important maturity indices for ber fruits, but specific gravity of the fruit and fruit colour are more suitable indices for determining maturity Ber plants start fruiting after first year of plantation in budded plants while seedling plants takes 3-4 years to come to fruiting. However, commercial production starts from third year onwards, hence the first year fruiting should not be allowed. The fruits of ber do not mature after harvesting. It is therefore, essential to harvest the fruits at an optimum stage of maturity. Harvesting is difficult in ber due to spiny nature of plants but the fruits are picked manually. Harvesting of fruits by shaking of fruit laden branches is also adopted. Under rainfed condition average yield per plant ranges from 10 to 52 kg with a rainfall of 125 mm and 850 mm respectively. However, under irrigated condition an average yield of 150-300 kg per plant (30-60 t ha^{-1}) can be obtained depending upon cultivar and location.

Ripening and storage: The ber fruits can be stored safely for about one week at room temperature and for about three weeks under cold storage. A 20 days storage period can be achieved by the combinations of 1% and 2% Ca with polyethylene bag under zero energy cool chamber was found to be effective in maintaining better quality of the fruit throughout the storage period in term of retention of acidity, ascorbic acid and total sugar (Bhasker *et al.*, 2006). Singh *et al.* (2008) observed that the Treatment with calcium nitrate (1.5%) and kept in the PPE (perforated polyethylene) bag is most efficient to retaining fruit quality, this treatment showed 21.3 and 10.8% PLW in Gola and Goma Kirti cultivars, respectively. Randhawa *et al.* (2009) observed that physiological loss in weight increases and fruit firmness decreases during storage. Fruits can be stored up to 20 days by pre-harvest spray of $CaCl_2$ (2%) and GA, (60 ppm) treatment, with min-

imum loss in quality. Vithlani and Patel (2010) found that titrable acidity, Flavonoid content, Flavonol content, DPPH radical scavenging capacity and ABTS radical scavenging capacity increased significantly in jujube wine and vinegar as compared to fresh jujube juice, while significant decrease in pH, total carbohydrate content, total phenol content and ferric reducing antioxidant power was observed during the same time period. The shelf- life of fruits can also be enhanced up to 30 days if the fruits are treated with 6 percent wax-emulsion and packed in perforated polythene bags of 100 gauge thickness, before storing in the commercial cold storage (7-8°C) and 85-90 percent RH.

Grading and packing: After harvesting of ber fruits, grading should be done to remove the undersized miss-happened, cankered and wind damaged fruits. 3-4 grades are generally used for grading *i.e.* A grade best fruits of large size, B-grade-medium sized good coloured fruits, C-grade small sized well coloured fruits and D-grade poorly coloured fruits of all sizes and left outs. The highest percentage of fruit falls in B-category followed by A grade. C and D grade may have just equal quantities. The A and B grade fruits are preferred in the market as well as by the consumers. A B and C grade fruits should be packed in corrugated fiber Board (CFB) cartoons, wooden crates, plastic crates, polynets or baskets of convenient sizes. D-Grade may be marketed in gunny-bags.

Value addition: Selling the products at the lowest market value just to survive economically is not sustainable. It can lead to stress on the land as well as on the farmer. Value-addition is simply anything we can do to raise the value of our product in the market. Value-added practices are the key to the future of sustainable farming, because they enable growers to advance economically. As a result of the change in physical state or the manner in which the agricultural commodity or product is produced and segregated, the customer base for the commodity or product is expanded and a greater portion of revenue is derived from the marketing, processing or physical segregation which is available to the producer of the commodity or product. It improve the profitability of the farmers, reduces the glut in market during peak season. Produce that cannot be stored can be converted into value added product increasing the profit margins of the farmers. This helps in empowering farmers and other weaker sections of society especially women through gainful employment opportunities and revitalize rural communities apart from providing better quality, safe and branded foods to the consumers, reduction in post-harvest losses, reduction of import and meeting export demands. Value addition encourages growth of subsidiary industries and reduces the economic risk of marketing thereby increasing opportunities for smaller farms and companies through the development of new markets.

Ber has immense potential in sustaining the income for farmers of arid and semi-arid regions of India by value addition. Procedure for ber candying was standardized by Singh *et al.* (1944), results showed that candy treated with sodium meta-bisulphite scored higher than those blanched with hot water. Ber Jams are most popular fruit preserves it is prepared from whole fruit, pieces of fruit, fruit pulp or fruit puree and with or without fruit juice or concentrated. Fruit juice as optimal ingredients and mixed with carbohydrate sweetener, with (or) without water and processed to a suitable consistency. Dubey *et al.* (2014) evaluated the quality of ber jam during storage period. The physicochemical attributes of ber jam showed that there were slight differences in the various constituents of ber jam made on 0.2 and 0.3% citric acid.

Ber fruits have high nutritive value, especially carbohydrates and vitamin C with good amounts of minerals like phosphorus, calcium and iron and high sugar to acid ratio at fully ripe stage. These attributes are ideal for a fruit to be dehydrated. Kumar and Nath (2002) studied dehydration of ber fruits and reported that there was non-significant difference in pretreatment and osmo-drying on fat content of ber fruits. The ash content of pre-treated air dried fruits was highest (0.63 %) as compared to untreated osmo dried fruits (0.51 %) and pre-treated osmo air dried (0.43 %). For making a superior dried product with ber, the fruits should be blanched for 5 minutes in boiling water before dehydration (Pareek, 1983).

Khurdiya (1980a) studied the effect of dehydration on different cultivars of ber *i.e.* Umran, Bagwari and Chhuara they were good for drying. Fruits having golden yellow to reddish brown colour were found superior for drying. Sulphuring at the rate of 150 g/ 8 kg of fruits was considered optimum. The rate of browning increased during storage for 6 months at room temperature (21-38°C). Chawan *et al.* (1993) studied processing of ber and papaya and indicated that the overall organoleptic score of ber tuty-fruity was better than that of papaya tuty-fruity. Kumar (2006) prepared ber powder by dehydrating ripe ber fruits using sun drying and oven drying techniques with different pre-treatments and reported that the powder contained total sugars 57.38%, reducing sugars 36.98%, non-reducing sugars 20.40% and ascorbic acid 35.17%. Kumar and Nath (2002) developed the conditions for preparation for chuhura like products from ber by osmo-air drying process.

Powder of Umran variety of ber was used for the development of value added products due to superior qualities. The products were developed under four categories which included traditional (custard and kheer), baked (biscuits and cake), extruded (pasta and noodles) and unfermented beverage (RTS beverage) by using different concentrations of ber powder. All the baked products had good acceptability scores. The traditional products and extruded products were best acceptable up to 30% supplementation while and

unfermented beverage up to 20% supplementation with ber powder. Results of nutritional analysis indicated that all the nutrients content increased as the supplementation level of powder increased except the protein content of baked and extruded products. All the stored products were organoleptically acceptable except RTS beverage prepared using 40% ber powder. Biscuits prepared with 10, 20 and 30% and pasta, noodles and RTS beverage prepared with 10 and 20% ber powder were best acceptable among all during storage. Fruit based beverages are becoming increasingly popular in the market with the growing consciousness of people in the nutritive value of fruits (Srivastava and Kumar, 2002). Investigations on preparation of various products from ber fruits (*Zizyphus mauritiana*) were conducted by Bal and Ranadhava (2005). They concluded that the juicy varieties such as Sanour-2, ZG-2, and Kaithli can be converted into pulp to serve as base material for squash. Khurdiya (1980a) studied a ready to serve (RTS) beverage containing 33.3% juice prepared from dried ber fruit after cooking and extracting the juice in a basket press. The juice had a pH of 3.75 and 19.6° Brix with 0.56% acidity. The juice extracted from ber fruits and processed at 80°C for 10 min. stored well for 9 months at room temperature (20-38°C). The beverage was organoleptically acceptable on evaluation.

Ber fruit are highly mucilageous, have low acidity and are not ideally suitable for pickling. Shobha and Bharati (2007) standardized the procedure for pickling of ber as a form of value addition. The acidulants used in pickle preparation were lemon and salt and three variants were prepared with varying concentrations of salt, lemon and spices. When freshly prepared, vinegar based pickle scored maximum for texture (2.73) and taste (2.86) compared to lemon based pickle. Lemon treated pickle was better accepted up to three months of storage compared to vinegar based pickle, both at the laboratory and consumer level. With the advancement of storage the loads of bacteria increased in pickle with lemon as acidifying agent. There were no fungal colonies in the vinegar added pickle throughout the storage period.

Conclusion

Ber (*Ziziphus nummularia*) holds immense potential for increasing the income of farmers in arid and semi-arid regions of India. This fruit boasts a range of diverse properties and uses, including neurological benefits (such as hypnotic, sedative, and anxiolytic effects), hypotensive and antinephritic properties, cardiovascular activity, immunostimulant effects, and various anti-fungal, anti-diabetic, anti-allergic, anti-ulcer, anti-inflammatory, anti-spastic, antioxidant, and antibacterial activities.

The applications of ber extend beyond its role as a food ingredient; it is also widely used in traditional medicine. This knowledge has been passed down through generations and may or may not be rooted in an understanding of the fruit's constituents. In regions where ber production is abundant, its traditional medicinal uses are particularly culturally relevant. The fruit is employed in Ayurvedic medicine as a tonic, aphrodisiac, and laxative, and it is known to alleviate biliousness, burning sensations, thirst, and vomiting. Additionally, it is beneficial in treating tuberculosis and blood disorders. The seeds of the ber fruit are used to treat eye diseases and can also be helpful in cases of leucorrhea. Ber is utilized in various forms in different countries around the world, earning it the titles of "king of arid fruit" and "desert apple."

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