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Growth, yield and physiological activity of differently drip-irrigated vegetable cowpea (*Vigna unguiculata*)

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ABSTRACT

A study was carried during rainy (*kharif*) seasons of 2019 and 2020 at College of Agriculture (Swami Keshwanand Rajasthan Agriculture University, Bikaner, Rajasthan), Bikaner, Rajasthan to determine the best irrigation level along with suitable cowpea [*Vigna unguiculata* (L.) Walp] variety for a hot-arid region where water is a very limited resource. The experiment was conducted in a split-plot design (SPD), consisted of 4 treatments of irrigation, viz. T_1, 40% PE; T_2, 60% PE; T_3, 80% PE; and T_4, 100% PE with 4 cowpea varieties, viz. Kashi Kanchan; Kashi Nidhi; Pusa Sukomal; and Swarna Mukut, replicated thrice. Irrigation at 100% PE was found superior for number of primary branches, no. of pods/plant, net photosynthesis rate and carboxylation efficiency over the irrigation treatment 60% PE and 40% PE while statistically at par with 80% PE irrigation level. The days taken to first flower appearance were recorded minimum with 40% PE irrigation level. Irrigation at 80% PE exhibited maximum number of pickings, pod diameter, average pod weight, yield and water-use efficiency (WUE). Maximum plant height, number of primary branches and nodules/plant were recorded with Kashi Nidhi. Minimum days taken to flower initiation, maximum number of pickings, highest pod diameter, maximum number of pods/plant, average pod weight (g) and yield (q/ha) were recorded by Swarna Mukut. Significantly higher net photosynthesis and carboxylation efficiency at pod formation were recorded with Swarna Mukut over the varieties Kashi Kanchan and Pusa Sukomal. Swarna Mukut exhibited significantly higher WUE (24.11 kg/ha mm) over Kashi Kanchan and Pusa Sukomal.

Keywords: Growth and yield parameters, Irrigation, Pan evaporation, Varieties, Vegetable cowpea

Cowpea [*Vigna unguiculata* (L.) Walp] is a significant leguminous vegetable crop grown for its nutritious grain, green pods, and fresh leaves, which are rich in both macro- and micronutrients such as carbohydrate, protein, vitamins, and minerals (Badiane *et al.* 2004, Carvalho *et al.* 2019, Bai *et al.* 2020, El Masry *et al.* 2021, Silva *et al.* 2021). According to Sprent *et al.* (2009), the haulms are used as feed for animals. It is referred to as "vegetable meat" because of the greater protein content (Gopalakrishnan 2007). Due to the crop's high vegetative growth, the area is entirely covered, preventing soil erosion. The cowpea has enormous potential as a substitute vegetable crop for dry land cultivation (Choudhary and Yadav 2011, Singh *et al.* 2022). In India, it is cultivated in Rajasthan, Uttar Pradesh, Madhya Pradesh, Karnataka, Jharkhand, Bihar, West Bengal, Punjab and Himachal Pradesh. In Rajasthan state, the total area under cowpea cultivation is 69 thousand hectares with production of 34 thousand MT (Anonymous 2020–21).

Most cowpeas are produced by small-scale farmers using rain-fed systems (Singh *et al.* 2003). Yield cannot be guaranteed in the absence of rainfall or when it is distributed unevenly since water shortages impair plant growth and flowering (Timko and Singh 2008). Indeed, studies have shown that a lack of water during flowering adversely affects cowpea yields (Anyia and Herzog 2004, Peksen 2007, Ahmed and Suliman 2010, Abdoul K *et al.* 2018). Families who depend on the cowpea run the risk of experiencing crop failure, starvation, and malnutrition. In situations where rainfall is unpredictable or insufficient to meet crop needs, irrigation helps stabilized output and provides farmers with insurance. Additionally, irrigation enables year-round production, particularly in the tropics and subtropics where the climate is ideal for cowpea development. Using effective irrigation systems like surface or subsurface drip irrigation (Dass *et al.* 2023, Singh *et al.* 2024), and other suitable agricultural water management strategies are necessary to conserve water and improve crop productivity *vis a vis* water-use efficiency. Thus, it

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was deemed vital to assess how cowpea respond to different irrigation levels under drip irrigation system.

MATERIALS AND METHODS

A study was carried during rainy (*kharif*) seasons of 2019 and 2020 at College of Agriculture (Swami Keshwanand Rajasthan Agriculture University, Bikaner, Rajasthan), Bikaner (28.09° N, 73.35° E and altitude 225 m above sea level), Rajasthan. The experiment was laid-out in a split-plot design (SPD) with irrigation as main-plot treatments and varieties as sub-plot treatments, replicated thrice. The experiment consisted of 4 treatments of irrigation, viz. T_1, 40% PE; T_2, 60% PE; T_3, 80% PE; and T_4, 100% PE with 4 cowpea varieties, viz. Kashi Kanchan and Kashi Nidhi taken from ICAR-Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh; Pusa Sukomal from ICAR-Indian Agricultural Research Institute, New Delhi and Swarna Mukut from ICAR Research Complex for Eastern Region Research Centre, Ranchi.

The crop was sown during the first week of July 2019 and 2020 at a distance of 30 cm × 60 cm in a paired row with plant to plant distance of 15 cm. Well decomposed farmyard manure @15 t/ha was applied at the time of field preparation. The fertilizers were given in the form of N:P:K in the ratio of 30:60:60 kg/ha during the whole crop growing season, out of which 15:45:45 kg/ha was applied by urea, Diammonium phosphate (DAP) and Muriate of Potash (MOP), respectively as a basal dose in a uniform manner to a whole field at the time of final field preparation. Remaining dose of nutrients were applied in the form of fertigation through 19:19:19 solution along with recommended irrigation. The laterals of drip system were online and dripper to dripper spacing was 30 cm and the discharge rate per dripper/emitter was 4 litre/h. Irrigation was scheduled based on climatological approach. Experimental data recorded in various observations were statistically analysed with the help of Fisher's analysis of variance technique (Fisher 1950).

P_n = Net photosynthesis rate (μmol/m^2/s) can be calculated as:

$$P_n = 120323.35 \times \frac{V \times P \times \Delta C}{\Delta t \times T_a \times A} = W \times \Delta C$$

where ΔC, CO_2 decrement from the initial reading (ppm or μmol/mol); V, Leaf chamber volume (litre); Δt, Time interval (seconds); T_a, Air temperature (K); P, Atmospheric pressure (bar); A, Leaf area (cm^2); W, Mass flow rate/leaf area (mol/m^2/s).

Carboxylation efficiencies were calculated as the initial slope of the Pn versus C response for each genotype:

$$\text{Carboxylation efficiency (mol/m}^2\text{/s)} = \frac{Pn}{CO_{2int}}$$

where P_n, Net photosynthesis (μmol/m^2/s); CO_{2int}, Internal CO_2 (ppm or μmol/mol).

Water use efficiency (WUE) was calculated as the ratio of pod yield to total water used in the particular treatment and expressed in kg/ha mm:

$$\text{WUE (kg/ha mm)} = \frac{\text{Pod yield (kg/ha)}}{\text{Water used (mm)}}$$

RESULTS AND DISCUSSION

Effect of irrigation regimes: The plant height at 60 DAS (days after sowing) was recorded significantly higher with 100% PE irrigation level over 60% and 40% PE. The per cent increase in plant height of vegetable cowpea with 80% PE was 13.57 and 39.60% over 60 PE and 40% PE, respectively at 60 DAS (Table 1). In case of 40% and 60% PE, the plant height was less might be due to arise of water deficit condition in plant tissue resulting in decline of leaf water content as well as reduction in both cell volume and cell turgor (Dasila *et al.* 2016, Gupta *et al.* 2017). Significantly higher number of primary branches at 60 DAS were found with 100% PE. The per cent increase in number of primary branches with 80% PE over the treatment 60% PE and 40% PE in tune of 21.50 and 73.97%, respectively on pooled mean data basis, was owing to better moisture regimes in the root zone.

The maximum number of nodules were counted with treatment 100% PE but it was statistically at par to 80% PE. The percentage increase in number of nodules per plant with 80% PE was in tune of 11.92 and 30.09% over the 60% and 40% PE as per pooled result analysis. It might be due to presence of sufficient moisture content in the rhizosphere of cowpea which enhances the activity of rhizobium bacteria around the root zone of a plant that ultimately enhanced the inoculation in root hairs or plant and leads to higher number of nodules in roots of cowpea plant.

The irrigation level 40% PE took the minimum days to flower initiation from day of sowing followed by 60% PE, 80% PE and 100% PE, respectively during both the years as well as in pooled result basis. The maximum number of pickings were recorded with 80% PE which was found at par with 100% PE and significantly higher over 60% and 40% PE irrigation levels, respectively. The increase in number of picking of pods with 80% PE was in tune of 16.88% and 40.94% over 60% and 40% PE, respectively on pooled mean basis. The pod diameter of vegetable cowpea recorded by 80% PE proved significantly superior over 60% and 40% PE, respectively but remains statistically at par with 100% PE.

The number of pods/plant recorded with 80% PE was significantly higher over 60% and 40% PE. As the irrigation applied with 100% PE from 80% PE, also increased the number of pods but it remained statistically at par to each other. Higher levels of moisture and nutrient concentration improved cell elongation and turgidity (Dadgale *et al.* 2014), increased photosynthesis by allowing the plant to capture more radiant energy, increased photosynthate translocation to the growing pods, and produced and retained more pods per plant at later stages of the crop cycle. Significantly higher average pod weight recorded with 80% PE, which

was statistically at par with 100% PE and proved superior over 60% and 40% PE. Sezen *et al.* (2005) had also noted that fresh bean length and width significantly affected over irrigation intervals. Irrigation at 80% PE obtained maximum yield per ha over 60% and 40% PE, but it was at par with 100% PE. Similar findings were reported by Dipikaben *et al.* (2018) and Patel and Kumari (2018).

A highest net photosynthesis rate was observed with 100% PE which was statistically at par with 80% PE irrigation level and significantly higher over 60% and 40% PE. Highest carboxylation efficiency was recorded with 100% PE which was at par with 80% PE. The carboxylation efficiency was recorded 0.06525 mol/m^2/s with 80% PE, which was significantly higher over 60% (0.06045 mol/m^2/s) and 40% PE (0.05248 mol/m^2/s) on pooled mean data basis.

The lowest depth of water applied was recorded with 40% PE followed by 60% PE but the water use efficiency was significantly higher with 80% PE which was found to be superior over 100%, 60% and 40% PE irrigation levels. The highest water use efficiency at 80% PE irrigation level indicated most effective water utilization for growth and development of plants. The similar findings in cowpea were reported by Mousa *et al.* (2017).

Response of varieties: The variety Kashi Nidhi recorded significantly higher growth parameters, viz. plant height at 60 DAS (73.09 cm), number of primary branches/plant at harvest (8.39) and highest number of nodules/plant (51.13) which was statistically at par with Kashi Kanchan and significantly superior over Pusa Sukomal and Swarna Mukut (Table 1). It might be due to the G × E (Genotype × Environment) interaction. Similar results were also reported by Peksen (2004), Abayomi and Abidoye (2009), Basaran *et al.* (2011), Nwofia *et al.* (2015), Asati *et al.* (2018) and Dipikaben *et al.* (2018). Ayisi *et al.* (2000) and Madukwe *et al.* (2008) also observed significant effect of varieties on number of nodules in cowpea.

Variety Swarna Mukut took minimum days for flower initiation followed by Pusa Sukomal, Kashi Nidhi and Kashi Kanchan. The variety Kashi Nidhi was found statistically at par with Kashi Kanchan. Similar results were also recorded by Peksen (2004) and Dipikaben *et al.* (2018) among 8 local cowpea genotypes. Babaji *et al.* (2011) had found that IT93K-4542-1 flowered and matured earlier among the four varieties studied. Highest number of pickings (7.13) was recorded in variety Kashi Nidhi which was statistically at par with Kashi Kanchan and significant over Swarna Mukut and Pusa Sukomal but highest pod diameter (6.34 mm) was recorded with variety Swarna Mukut which was statistically at par with Kashi Nidhi and significantly higher over Kashi Kanchan and Pusa Sukomal. These findings were in conformity with Peksen (2004), Pandey *et al.* (2006) and Basaran *et al.* (2011) who reported that pod diameter and pod length differs significantly over the varieties. Highest number of pods per plant was recorded with variety Swarna Mukut (22.46 pods) which was statistically at par with Kashi Nidhi and significantly higher over Kashi Kanchan and Pusa Sukomal. The number of pods per plant increased

Table 1 Effect of irrigation levels and cultivars on growth, yield, physiological parameters and water management studies of vegetable cowpea

Treatment	Plant height at 60 DAS (cm)	Primary branches/ plant	Nodules/ plant	Days taken to flower initiation	No. of pickings	Pod diameter (mm)	Pods/ plant	Average pod weight	Yield (q/ha)	Net photosynthesis at pod formation stage (µmol/m^2/sec)	Carboxylation efficiency at pod formation stage (mol/m^2/sec)	Water-use efficiency (kg/ha mm)
Irrigation levels												
40% of PE	50.81^{c}	4.84^{c}	37.59^{c}	37.98^{c}	5.08^{c}	4.83^{b}	15.77^{c}	3.19^{c}	78.08^{c}	36.97^{c}	0.05248^{b}	16.94^{c}
60% of PE	62.45^{b}	6.93^{b}	43.69^{b}	41.36^{b}	6.10^{b}	5.72^{a}	19.49^{b}	4.23^{b}	127.91^{b}	43.75^{b}	0.06045^{a}	22.20^{a}
80% of PE	70.93^{a}	8.42^{a}	48.90^{a}	43.56^{a}	7.13^{a}	6.08^{a}	22.61^{a}	4.60^{a}	159.16^{a}	47.68^{ab}	0.06525^{a}	23.02^{a}
100% of PE	73.86^{a}	9.17^{a}	51.13^{a}	44.17^{a}	6.97^{a}	6.06^{a}	22.71^{a}	4.53^{ab}	157.67^{a}	49.99^{a}	0.06575^{a}	19.57^{b}
SEm. ±	1.26	0.25	0.89	0.40	0.13	0.12	0.33	0.09	2.78	1.21	0.00158	0.47
CD (P=0.05)	3.88	0.77	2.74	1.22	0.39	0.36	1.00	0.28	8.55	3.72	0.00486	1.46
Varieties												
Kashi Nidhi	73.09^{a}	8.39^{a}	50.92^{a}	42.92^{a}	6.59^{b}	6.08^{a}	22.13^{a}	4.28^{ab}	147.29^{a}	41.94^{c}	0.06322^{b}	23.11^{a}
Kashi Kanchan	67.14^{b}	7.89^{a}	48.75^{a}	43.78^{a}	6.07^{c}	5.35^{b}	18.84^{b}	4.04^{bc}	118.93^{b}	46.33^{b}	0.05513^{c}	18.51^{b}
Pusa Sukomal	56.05^{d}	6.09^{c}	38.75^{c}	41.18^{b}	5.45^{d}	4.92^{c}	17.14^{c}	3.81^{c}	102.76^{c}	38.96^{c}	0.05030^{c}	15.99^{c}
Swarna Mukut	61.77^{c}	6.99^{b}	42.89^{b}	39.19^{c}	7.17^{a}	6.34^{a}	22.46^{a}	4.40^{a}	153.94^{a}	51.15^{a}	0.07529^{a}	24.11^{a}
SEm. ±	1.18	0.18	0.79	0.31	0.11	0.10	0.27	0.09	2.51	1.13	0.00185	0.41
CD (P=0.05)	3.36	0.52	2.24	0.88	0.33	0.27	0.77	0.25	7.14	3.21	0.00525	1.17

Values within columns with different letters (superscript) are significantly different according to Duncan's test at P=0.05. DAS, Days after sowing.

Table 2 Interaction effect of irrigation levels and varieties on yield and yield contributing traits of vegetable cowpea

Varieties	Drip irrigation levels (PE)																			
	Pod length (cm)					Pods/plant					Average pod weight					Yield (q/ha)				
	40%	60%	80%	100%	Mean	40%	60%	80%	100%	Mean	40%	60%	80%	100%	Mean	40%	60%	80%	100%	Mean
Kashi Nidhi	24.29	26.16	27.60	27.28	26.33	16.84	21.72	24.92	24.80	22.07	3.23	4.37	4.65	4.62	4.22	92.32	147.90	176.65	173.34	147.55
Kashi Kanchan	23.55	25.00	26.87	26.65	25.52	15.08	18.44	21.03	20.98	18.88	3.26	4.03	4.41	4.39	4.02	69.72	116.84	144.87	144.30	118.93
Pusa Sukomal	16.73	17.71	20.64	20.38	18.86	13.21	15.66	19.88	19.80	17.14	3.14	3.69	4.20	4.16	3.80	56.48	95.59	129.87	129.14	102.77
Swarna Mukut	18.13	21.12	24.08	23.20	21.63	17.92	22.14	25.07	24.98	22.53	3.46	4.46	4.87	4.81	4.40	94.56	151.56	185.50	184.15	153.94
Mean	20.67	22.50	24.80	24.38		15.76	19.49	22.72	22.64		3.27	4.14	4.53	4.50		78.27	127.97	159.22	157.73	
		S.Em. ±		CD (P=0.05)			S.Em. ±		CD (P=0.05)			S.Em. ±		CD (P=0.05)			S.Em. ±		CD (P=0.05)	
I at same level of V		0.26		0.74			0.23		0.65			0.06		0.18			0.42		1.24	
V at same level of I		0.35		1.00			0.32		0.92			0.09		0.26			0.43		1.25	

in tune of 19.21 and 31.04 with Swarna Mukut over the varieties Kashi Kanchan and Pusa Sukomal, respectively. Addo-Quaye *et al.* (2011) also observed that number of seeds were significantly affected with the varieties.

The variety Swarna Mukut recorded maximum average pod weight which was found at par with Kashi Nidhi and significantly higher over Kashi Kanchan and Pusa Sukomal. Results revealed that maximum yield of pods/ha was recorded with Swarna Mukut variety which was statistically at par with variety Kashi Nidhi and significantly higher over Kashi Kanchan (118.93 q/ha) and Pusa Sukomal (102.76 q/ha). Similar findings were reported by Naim and Jabereldar (2010), Babaji *et al.* (2011), Basaran *et al.* (2011), Patel *et al.* (2011), Peksen and Peksen (2013), Nwofia *et al.* (2015), Dipikaben *et al.* (2018) and Patel and Kumari (2018).

Net photosynthesis at pod formation stage was recorded maximum with Swarna Mukut. Swarna Mukut was also found high yielder as compared to other varieties which indicates that it conserves more photosynthates in pods as compared to other varieties which was the result of high carbon dioxide accumulation in form of carbohydrates. The similar findings were recorded by Hayatu and Mukhtar (2010) and Moreira *et al.* (2016). Mwale *et al.* (2017) reported that the efficiency of photosystem-II is relatively affected with cultivars. Results indicated that water use efficiency of cowpea significantly influenced due to varietal treatments. Swarna Mukut showed highest water use efficiency. Similar findings were observed by Singh *et al.* (2021) for fennel.

The interaction effect of drip irrigation levels and varieties was found significant on pod length (cm), number of pods per plant, average pod weight (g) and yield (q/ha) during both the years of experimentation and in pooled analysis (Table 2). Drip irrigation level at 80% PE with variety Kashi Nidhi produced maximum pod length (27.60 cm) followed by 100% PE with Kashi Nidhi (27.28 cm). Drip irrigation level 80% PE with variety Swarna Mukut recorded highest number of pods/plant (25.07) which were higher from irrigation level 60% and 100% PE with the same variety. Drip irrigation level at 80% PE with Swarna Mukut variety produced highest average pod weight (4.87 g). However, it was statistically at par with 80% PE with Kashi Nidhi (7.65 g). Maximum yield (185.50 q/ha) was recorded with Swarna Mukut variety at drip irrigation level of 80% PE followed by Kashi Nidhi (176.65 q/ha) at same level of irrigation. Bhunia *et al.* (2015) also recorded significant interaction of irrigation levels with cultivars in fenugreek for yield and yield attributing traits. Ahmed and Suliman (2010) in cowpea, El-Noemani *et al.* (2010) in snap bean and Kumar *et al.* (2015) in cluster bean, recorded that the yield and yield attributing traits were significantly affected with the level of applied water. Wang and Xing (2017) evaluated the effects of irrigation and fertilization on the fruit yield and quality, water use efficiency (WUE) and fertilizer partial factor productivity (PFP) of tomatoes and found interactions between irrigation and fertilization treatments and individual factors of irrigation and fertilization significantly (P<0.01) affected fruit yield, WUE and PFP.

Based on the 2-years study it can be concluded that, growth, yield and physiological activities of plant are not only a function of applied water but these are also the function of amount of water applied. Irrigation scheduling at 80% pan evaporation which based on daily evaporation is more efficient for growth, yield and physiological activities of vegetable cowpea. Growth, yield and physiological activities of plant are also the result of interaction between varieties and environment. Swarna Mukut and Kashi Nidhi varieties were found to be suitable for cultivation in arid western region of Rajasthan during *kharif* season, and these varieties should be irrigated at 80% PE for higher yields and water-use efficiency.

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