



Growing Environments and Micronutrients Application Influence Fruit and Seed Yield of Capsicum (*Capsicum Annum*)



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Abstract

Field experiments were carried out to standardize agro-techniques for higher productivity of capsicum in cold arid region of Ladakh. The experiments consisted of effect of growing environments (viz., under ground trench, polycarbonate green house, polyench and open condition) and micronutrients (zinc, boron, manganese, magnesium, and copper) spray on yield performance and quality of capsicum var. California Wonder, Pusa Deepti and Yolo Wonder. Results revealed the significant effect of growing environments on marketable traits of capsicum. Fruit yield was found maximum under triple layer polycarbonate greenhouse (634.0g/plant) exhibiting 115% increment over open control (294.0g/plant). Among the micronutrients spray, two sprays of zinc (100ppm) or boron (100ppm) were found best under greenhouse conditions for obtaining higher yield and quality of capsicum exhibiting fruit yield of 840.96g per plant significantly superior over control (768.43g per plant) irrespective of the variety. Interaction effects of micronutrients to variety were significant for marketable traits of capsicum. In case of seed recovery, polycarbonate greenhouse was found best exhibiting the highest seed yield (4.01 to 4.39g/plant) with better test weight (5.62 to 5.76g).

Keywords: Greenhouse peppers; *Capsicum annum*; Micronutrient; Fertilization; Protected cultivation

Introduction

Greenhouse grown capsicum (*Capsicum annum L.*) is one of the remunerative crops in hilly areas of northern and southern India. It is a delicacy in the Indian culinary items and also a source of vitamins, minerals and antioxidants [1]. Its local availability in the Ladakh sector is very low and demand is met through transport from far areas which led to excessive losses and deterioration of quality due to its perishable nature [2]. Inclement weather, fluctuation in temperature and high winds in these hilly areas lead to its poor production in open fields [3]. Protected structures like polyhouse, polytunnels, and plastic mulches have been found very useful for growing capsicum in hilly areas [4-6] with high quality produce [7,8]. Secondly, soil of this region is not very fertile [9] therefore role of balanced nutrition become important to raise a good crop with higher productivity. Micronutrients, being a key component of IPNM and necessary for biosynthesis of several plant enzymes, have proved their importance in quality vegetable production in capsicum [10], tomato [11], cucumber [12], garlic [13] and cauliflower [14]. Micronutrients especially zinc and boron as an essential trace elements promote growth and development, flowering and fruiting [15-18]. No information is available on the effect of various structures on the productivity of this crop in this region as well as effect of micronutrients on fruit and

seed production potential. Therefore, this study was carried out to standardize capsicum cultivation under protected structure in this region to ensure the availability of this crop, increase the productivity and extend the time of availability with better quality fresh fruits to the locals as well as to the armed forces deployed in this far flung region of the country.

Materials and Methods

Experimental site and treatments

The experiments were carried out at Field Research Laboratory Research Station at Partapur, Nubra valley, Siachen sector of Ladakh situated at about 9500 ft above MSL. The temperature of this area varies from -20 °C (Jan) to 32 °C (Aug). The average temperature during crop season varied from 14-20 °C (max) and 4-6 °C (min). The soil was sandy with pH 7.44, electrical conductivity 0.13mmhos/cm, organic C 0.58%, available P (10.05kg/ha) and available K (260kg/ha), zinc (2.68ppm), copper (1.87ppm), iron (22.33) and manganese (32.06ppm). The first experiment consisted of four growing environments (viz., under ground trench, polycarbonate green house, polyench and open condition). Four-weeks-old seedlings of capsicum var California Wonder were transplanted during first week of May at a spacing of 45×45cm during both the years. The second experiment

consisted of six micronutrient treatments, viz Mg (100ppm) as magnesium sulphate, Cu (100ppm) as copper sulphate, Mn (100ppm) as manganese sulphate, Zn (100ppm) as zinc sulphate, B (100ppm) as borax, and control (no spray) on three varieties of capsicum viz., California Wonder, Pusa Deepti and Yolo Wonder. Four-weeks-old seedlings of all three capsicum cultivars were transplanted during first week of May at a spacing of 45 × 45cm in polycarbonate greenhouse. Two sprays of each were made after 30 and 45 days of transplanting in all the three replications. All recommended cultural practices were done uniformly in all the treatments of both experiments. The fertilizer dose of 100:80:60kg N:P:K/ha in the form of urea, DAP and muriate of potash was applied. Full dose of P and K along with half of the N was applied as basal while rest of the N was applied as top dressing in two splits after 30 and 45 days of transplanting.

Statistical analysis

Observations were recorded on plant growth and yield parameters along with seed recovery. Data were analyzed statistically as per the standard procedure.

Details of the structures used

Underground Trenches: This is the very simple, cheap and potentially useful structure. A trench of 30×10×3 (Lx W x H) ft was used to grow crop. The sides of the pit are adequately plastered with mud or mud bricks to avoid falling of the soil during cultural operations. Wooden or iron poles are used to support the UV stabilized polyethylene sheet of 200 micron over the trench. Being an underground structure, it provides protections from winds, reduces heat loss during night hours and maintains better temperature during daytime thus allowing better growth and finally yield. Cultural operations are done by rolling over the polyethylene sheets.

Double-wall polyench: The term polyench is the abbreviation of a polyhouse constructed over a trench. The design of the structure is done by FRL (DRDO) Leh. The structure is made up of local material leading to low cost. The structure is of the shape of gable uneven span with sides of the structures are double-walled and made of mud bricks. Mud bricks are used as they provide better insulation and loose heat slowly compared to stone. The double walls are spaced at 15cm and gap is filled with insulating material like saw dust to improve the heat retention. The side walls are descending

towards the front till the ground level with the provision of gate towards the back wall. The roof is like uneven span greenhouse. The sun facing roof towards the south is larger than northern side roof. The sun facing roof is built with UV stabilized polyethylene/FRP sheet supported over a wooden frame whereas the other side roof is made of grass thatch with provision of ventilators. The inner sides of the walls are painted black to trap more heat. The back wall is 7ft high.

Polycarbonate greenhouse: A triple layered polycarbonate greenhouse (10mm thick) with more than 80 per cent light transmissibility with provision of side windows for natural ventilation was used for experimentation.

Results and Discussion

Analysis of variance revealed the significant effect of various protected structures on the horticultural traits and seed related traits of capsicum during both the years. The results also revealed that various protected structures exhibited the significant effect of their growing conditions on various horticultural and yield related traits during both the years (Table 1 & 2). Plant height was the minimum in open condition (28.0cm) and the maximum under polyench (95.67cm) followed by polycarbonate and trench (Table 3). Plant height was significantly superior under all protected structures. Interestingly, plants were excessively long under polyench but this may be attributed to the shade effect which is experienced by this structure due its partial underground nature and partial mud wall. Similar trend was noticed during second year also though the plant height was better under open conditions (34.0cm) compared to first year (Table 4). Number of fruits per plant also varied significantly under different growing structures with the maximum under polycarbonate (7.93 and 7.27, respectively) whereas the minimum under open condition (4.50 and 4.87, respectively) during both the years. No significant difference was noticed in the number of fruits per plant between polyench and open vis-à-vis polycarbonate and trench. During both the years, average fruits weight was the maximum under polycarbonate (90.4 and 92.67g) significantly superior over open condition and statistically at par with other two structures. Fruit size also affected significantly during both the years and the largest fruits were recorded under polyench (8.10cm) during first year and under polycarbonate (7.27cm) during second year significantly superior over open but statistically at par among the protected structures.

Table 1: ANOVA for various yield attributing traits in capsicum during first year

Source	df	Plant height (cm)	Fruits/plant	Ave. Fruit Wt (g)	Fruit length (cm)	Fruit yield/plant (g)	Seed: Flesh ratio	Seeds/fruit	1000 seed wt (g)	Seed yield/plant (g)
Replication	2	9.65	0.21	31.25	0.025	1193.2	0.008	316.3	0.042	0.794
Treatment	3	2476.2**	9.83**	487.8**	1.17	71535**	0.0036	1204.7**	0.075*	5.525**
Error	6	44.65	0.85	37.11	0.427	7275.8	0.0009	62	0.0115	0.378

Table 2: ANOVA for various yield attributing traits in capsicum during second year.

Source	df	Plant height (cm)	Fruits/ plant	Ave. Fruit Wt (g)	Fruit length (cm)	Fruit yield/ plant (g)	Seed: Flesh ratio	Seeds/ fruit	1000 seed wt (g)	Seed yield/ plant (g)
Replication	2	24.08	0.225	9.75	0.145	759.1	0.0015	60.75	0.0023	0.16
Treatment	3	1387.3**	3.95**	595.2*	0.323**	67796**	0.0059**	1120.2**	0.031	4.19**
Error	6	15.42	0.21	71.8	0.01	749.3	0.0003	77.96	0.0074	0.142

* and ** indicate significant at 5 and 1% level of significance respectively

Table 3: Effect of various protected structures on yield attributing traits in capsicum during first year.

Treatment	Plant height (cm)	Fruits/ plant	Ave. Fruit Wt (g)	Fruit length (cm)	Seed: Flesh ratio	Seeds/ fruit	1000 seed wt (g)
Trench	45.6	7.27	80	7.43	0.27	87.33	5.44
Polycarbonate	52.57	7.93	90.4	6.8	0.22	99.67	5.76
Polyench	95.67	4.5	90.2	8.1	0.19	84.67	5.58
Open	28	4.5	63.2	6.8	0.21	52.67	5.42
SEm ±	5.46	0.75	4.97	0.533	0.03	6.43	0.08
CD (p=0.05)	13.36	1.85	12.18	1.3	NS	15.75	0.21

Table 4: Effect of various protected structures on yield attributing traits in capsicum during second year

Treatment	Plant height (cm)	Fruits/ Plant	Ave. Fruit Wt (g)	Fruit length (cm)	Seed: Flesh ratio	Seeds/ Fruit	1000 Seed wt (g)
Trench	47	6.47	79.33	7.13	0.22	80	5.46
Polycarbonate	57	7.27	92.67	7.27	0.25	98	5.62
Polyench	84.7	5.07	83.67	7.13	0.21	70.3	5.48
Open	34	4.87	59.33	6.53	0.15	51.6	5.38
SEm ±	3.21	0.37	6.92	0.08	0.014	7.21	0.07
CD (p=0.05)	7.85	0.92	16.95	0.2	0.035	17.66	NS

Fruit yield which is the most important trait for economics of the cultivation also affected significantly by the growing environment of the structures. The maximum fruit yield per plant was observed under polycarbonate house (634.0g and 630.0g, respectively) during both the years significantly superior over open where it was the lowest (294.0 and 286.0g) (Figure 1 & 2). The fruit yield under polycarbonate was also significantly superior over polyench during both the years and over trench during second year. The superiority in the fruit yield in polycarbonate may be attributed to the more number of fruits per plant with comparatively heavier weight inside this structure compared to open condition and other structures. These findings suggest that protected structures of any kind is better over open condition in these area to grow capsicum because fruit yield increases from 32.5 (polyench) to 117.5% (polycarbonate) over control, pooled over two years. These findings also revealed that low cost protected structures like underground trenches are really better option for growing these vegetables as fruit yield increment is in the range of 85%.

Capsicum enjoys assured market in Ladakh and fetches good price in market, therefore has vast potential [19]. Quality seed production is always a problem in open mostly due to lack of agro-techniques and secondly seedlessness of fruits grown outside in open due to low temperatures during night [2]. Protected environment provides opportunity to grow vegetables successfully for table purpose. Present findings revealed that seed related traits also affected significantly by growing structures. Seed to flesh ratio was better inside the protected structures. Average number of seeds per fruit was the minimum (52.67 and 51.6, respectively) under open condition whereas the maximum under polycarbonate (99.67 and 98.0, respectively) during both the years. This may be attributed to the smaller sized fruits obtained in open conditions which are ultimately the effect of poor weather conditions and fluctuating temperature. Seeds harvested from the protected structures were also bold as exhibited by the 1000 seed weight that was comparatively higher in protected structures over the open conditions. Seed yield per plant was

found significantly higher under polycarbonate (4.39 and 4.01g, respectively) during both the years over open as well as polyenich (Figure 1 & 2).

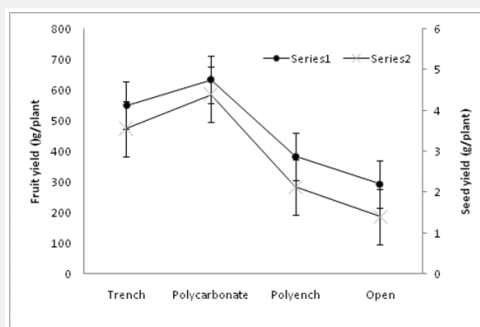


Figure 1: Effect of growing environments (Trench, polycarbonate, polyenich and open) on fruit yield (series 1) and seed yield (series 2) of capsicum var California wonder during second year. Data presented in the average of five plants. Value of critical difference to compare the means for fruit yield is 54.75 and for seed yield is 0.75 at P= 0.05. Error bars represent the standard error values.

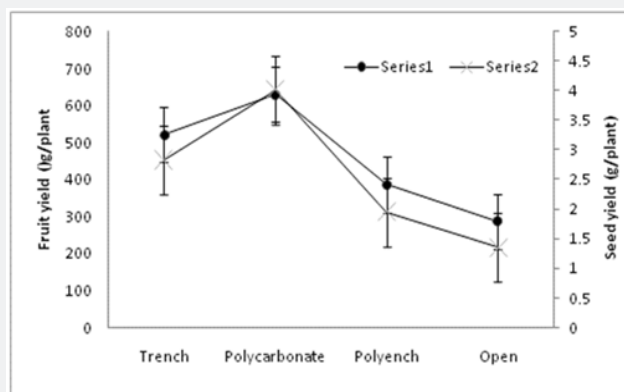


Figure 2: Effect of growing environments (Trench, polycarbonate, polyenich and open) on fruit yield (series 1) and seed yield (series 2) of capsicum var California wonder during first year. Data presented in the average of five plants. Value of critical difference to compare the means for fruit yield is 170.63 and for seed yield is 1.23 at P= 0.05. Error bars represent the standard error values.

Micronutrients, being a key component of IPNM and necessary for biosynthesis of several plant enzymes, have proved their importance in quality vegetable production. Analysis of variance revealed the significant effect of micronutrient spray, variety and their interaction on the quantitative traits of the capsicum. Spray of micronutrients exhibited increase in number of fruits per plant compared to control in all three varieties of capsicum (Table 5 & 6). The average value for the trait was the maximum under zinc spray. Average fruit weight also exhibited the beneficial effect of micronutrient spray over control. The value averaged over all three varieties exhibited that zinc spray treatment resulted into heavier fruits. Fruit yield per plant varied from 681.7 to

Table 5: Effect of micronutrients spray on capsicum grown in polycarbonate greenhouse during I year.

Treatment	No. of fruits/plant			Ave. fruit wt (g)		
	CW	PD	YW	CW	PD	YW
Control	11.6	12.6	11	60.7	71.8	92.2
Mg(100 ppm)	12.1	12.9	11.7	65.7	72.9	94.8
Cu (100 ppm)	12.4	13.2	12.1	63.4	74.2	112.5
Mn(100 ppm)	12.4	12.9	12.1	61.2	75.5	108.9
Zn (100 ppm)	12.6	13.5	12.3	67.2	78.5	113.2
B (100 ppm)	12	12.8	11.2	62.9	74.2	105.1
LSD (P<0.05)	Variety = 0.306			Variety = 7.26		
	Micronutrients = 0.433			Micronutrients = 10.27		
	Interaction = 0.749			Interaction = 17.80		

758.0g for California wonder, 782.3 to 842.6 g for Pusa Deepti and 841.3 to 922.3g for Yolo wonder under various treatments (Figure 3 & 4). Fruit yield was the minimum under control and the maximum in zinc spray treatment. It is clear from the results that among the micronutrients, zinc (100ppm) spray twice before onset of flowering is beneficial in increasing the marketable yield by 10-13% and size of fruits in capsicum. Beneficial effect of zinc sulphate (0.4%) and boric acid (0.1%) has been reported in garlic by Srivastava et. al. Improvement in the fruit weight and size due to spray of micronutrients may be attributed to the role of these elements in the plant nitrogen metabolism, carbohydrate metabolism and translocation of photosynthates as reported by [10,11,15,16,20,21].

Table 6: Effect of micronutrients spray on capsicum grown in polycarbonate greenhouse during II year.

Treatment	No. of fruits/plant				Ave. fruit wt (g)			
	CW	PD	YW		CW	PD	YW	
Control	12	12.3	10.6		56.9	53.7	71.2	
Mg(100 ppm)	12	12.7	11.3		60.7	58.2	72.5	
Cu (100 ppm)	12.7	13	11.7		63.7	61.9	79.9	
Mn(100 ppm)	12.5	12.8	12.1		62.2	60.5	80.3	
Zn (100 ppm)	12.6	13.4	12		64.1	58.5	82.1	
B (100 ppm)	12	12.9	11.3		62.5	62.7	80.5	
LSD (P<0.05)	Variety = 0.958				Variety = 1.88			
	Micronutrients = 0.677				Micronutrients = 2.66			
	Interaction = 1.65				Interaction = 4.60			

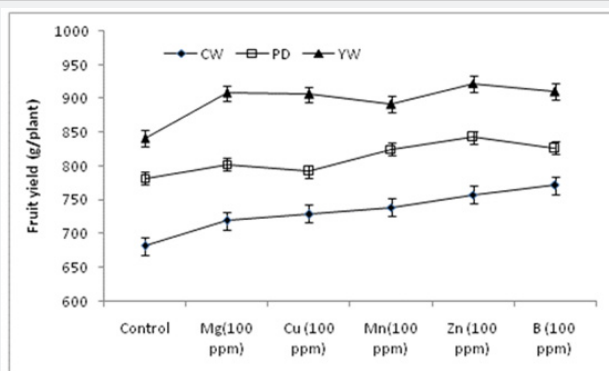


Figure 3: Effect of micronutrient spray of fruit yield of capsicum variety California Wonder (CW), Pusa Deepti (PD) and Yolo Wonder (YW) under polycarbonate house during first year. Values presented are mean of five plants. Factorial analysis revealed LSD values ($p < 0.05$) for Variety = 50.19, Micronutrients = 70.97 and Interaction = 122.94. Error bars represent the standard error values.

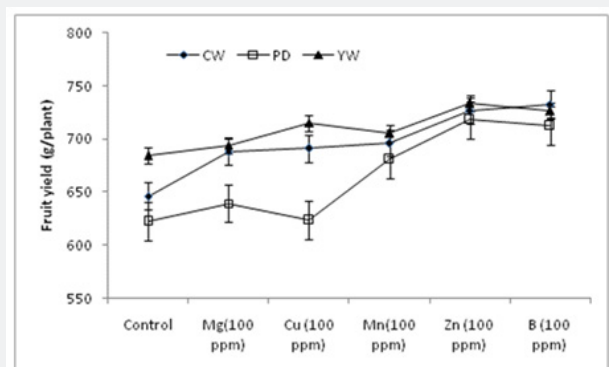


Figure 4: Effect of micronutrient spray of fruit yield of capsicum variety California Wonder (CW), Pusa Deepti (PD) and Yolo Wonder (YW) under polycarbonate house during second year. Values presented are mean of five plants. Factorial analysis revealed LSD values ($p < 0.05$) for Variety = 14.25, Micronutrients = 20.15 and Interaction = 34.91. Error bars represent the standard error values.

Conclusion

The study revealed that protected conditions are better for fruit and seed yield of capsicum in higher altitude. Fruit

yield was found maximum under triple layer polycarbonate greenhouse exhibiting 115% increment over open control. Among the micronutrients spray, two sprays of zinc (100ppm) or boron (100ppm) were found best under greenhouse conditions for obtaining higher yield and quality of capsicum irrespective of the variety. Interaction effects of micronutrients to variety were significant for marketable traits of capsicum. In case of seed recovery, polycarbonate greenhouse was found best exhibiting the highest seed yield with better test weight. Therefore farmers can motivated to use protected cultivation technology may it be low cost to have remunerative crop with spray of micronutrients to increase the fruit and seed quality.

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