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Response of bell pepper (*Capsicum annuum*) to different agro-techniques and NAA application

PRIYANKA BIJALWAN[1]*, SHILPA[2] and PRASHANT KAUSHIK[3]

Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, 173 230, India

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ABSTRACT

An experiment was conducted during the rainy (*kharif)* seasons of 2017–18 and 2018–19 at the research farm of Dr. Y S Parmar University of Horticulture and Forestry in Nauni, Solan, Himachal Pradesh to study the effects of different planting methods, mulches and the addition of natural organic acids (NAAs) on bell pepper (*Capsicum annuum* L.) growth and yield. The experiment involved 12 different treatments of 2 planting methods, 3 mulching levels, and 2 levels of NAA in a Randomized Block Design (Factorial) and 3 replications. The yield and its characteristics were shown to be highly impacted by planting methods, mulch material, and NAA levels. In terms of maximum plant height, early blooming, maximum fruit length, fruit width, fruit weight, fruits/plant, fruits/plot, and yield/ha, P_1, M_2, and N_1 each stood out as the best. The raised bed planting technique with silver/black polythene mulch and NAA treatment @15 ppm at 30 and 45 days after planting ($P_1M_2N_1$) resulted in the highest plant height, days to 50% flowering, fruit length, fruit breadth, fruit weight, number of fruits/plant, yield/plot and yield/ha. According to the findings, in the mid-hill conditions of Himachal Pradesh, the treatment $P_1M_2N_1$ achieved the highest levels of yield and its attributing features.

Keywords: Bell pepper, Mulch, Naphthalene acetic acid, Planting method

The bell pepper (*Capsicum annuum* L.) is a high-end ingredient, widely eaten all over the world. In India, 496 thousand metric tonnes (MT) of bell peppers are harvested every year, with productivity of 14.59 t/ha from an area of 34 thousand ha. Himachal Pradesh is the primary provider of bell pepper to the plains throughout the summer and wet seasons. Himachal Pradesh's 2.59 thousand hectares of bell pepper fields yield 59.52 thousand tonnes of peppers annually (NHB 2015–2016). However, there is a lack of quantitative evaluation for a regional/crop-specific system and further implementation of best management practices to mitigate the environmental concerns associated with intensive vegetable production. So, there is a need to improve the quantity and quality of crops through different agro-techniques.

Farmers in various regions of the globe have been using raised bed agriculture techniques for eons. During vegetable production, increasing soil tillage causes soil compaction and depletion, which affects crop output (McHugh *et al.* 2009). Raised beds must be implemented in order to get the benefits of no-till planting. In addition to increasing crop output and reducing the risk of waterlogging and salinity, raised beds also save irrigation water (Bakker *et al.* 2010). Raised beds mitigate weed infestation (Miernicki *et al.* 2018) and provide better mid-season field access for intercultural operations. Mulches are employed in agriculture for a multitude of reasons, the most significant of which are weed suppression, and soil erosion management. Mulching also encourages soil microorganisms and conserves soil moisture and temperature, resulting in improved organic matter development in the soil (Sharma and Bhardwaj 2017).

Hormonal imbalance in the plant influences flower and fruit drop under adverse circumstances (Quinet *et al.* 2019). Rapid cell elongation and cell division in the meristem are thought to be a direct outcome of NAA's positive impact, which is ascribed to an enhanced rate of photosynthetic activity, quicker transport and efficiency of using photosynthetic products (Muller and Munne-Bosch 2021). In consideration of the aforementioned, studies into the effects of NAA (auxin) treatments and other agro-techniques on bell pepper growth and production were performed.

[1]Himgiri Zee University, Sherpur, Chakrata Road, Dehradun, Uttarakhand; [2]CSK Himachal Pradesh Agriculture University Palampur, Himachal Pradesh; [3]Instituto de Conservacion y Mejora de la Agrodiversidad Valenciana, Universitat Politècnica de Valencia, Valencia, Spain. *Corresponding author email: priyankabijalwan24@gmail.com

MATERIALS AND METHODS

An experiment was conducted at the research farm of

Dr. Y S Parmar University of Horticulture and Forestry in Nauni, Solan, Himachal Pradesh during rainy *(kharif)* seasons, April 2017 to August 2018. A bell pepper Solan Bharpur, high-yielding open-pollinated variety, selected from a segregating population with four-lobed fruits was used for this research. This variety has received a tremendous response from the capsicum-growing farmers of the state, being a very popular variety well suited for the mid-hills of Himachal Pradesh. The experiment was designed as a Randomized Block Design (RBD) with 3 replicates and 12 treatments [2 planting techniques (P_1, raised bed; P_2, flat-bed), 3 mulch levels (M_1, black polythene mulch; M_2, silver/black polythene mulch; M_3, no NAA application), and 2 NAA (Naphthalene acetic acid) (N_1, @15 ppm at 30 and 40 days after transplanting; N_2, no NAA application) levels] (Table 1). The distance between the two beds was 45 cm, and the elevated bed itself was 15 cm above ground level. In April 2017 and April 2018, seedlings were planted at 60 cm × 45 cm spacing on well-prepared plots. Plots were 1.20 m × 9.45 m, with a maximum of 42 plants per plot. Plots were treated with either black polythene mulch (50) or silver/black polythene mulch (50 µ) of 200-gauge thickness. Mulches were spread throughout the plots, and then holes were cut into the mulch in accordance with the suggested plant spacing. In pre-prepared plots, seedlings were spaced at 60 cm × 45 cm, with each plot holding 42 plants. The plots had dimensions of 1.20 m × 9.45 m.

RESULTS AND DISCUSSION

Effect of planting methods: Plant height, days to 50% flowering, fruit length, fruit width, fruit weight, number of fruits/plant, yield/plot, and yield/hectare all differed significantly depending on planting technique, mulching, and NAA levels (Table 2). The plants planted on raised beds (P_1) produced the tallest plants (66.58 cm), early flowering (30.79), maximum fruit length (6.61 cm), fruit width (5.62 cm), fruit weight (46.93 g), number of fruits/plant (23.50), yield/plot (46.46 kg), and yield/ha (327.74 q), whereas the least plant height (63.49 cm), more days to 50% blooming (31.78), minimum fruit length (6.34 cm) fruit breadth (5.40 cm), fruit weight (46.21 g), number of fruit/plant (22.65), yield/plot (44.12 kg) and yield/ha (311.28 q) was recorded in those plants grown on flat-bed (P_2). The soil does not compact on raised beds, and the plants suffer less harm from limited cultural practices. By reducing traffic and improving soil quality, plant growth is stimulated (McHugh *et al.* 2009). Tillage and the increased availability of nutrients on a raised bed allow for taller plants due to increased assimilation of both macro and micronutrients (Verma *et al.* 2016). Kumar and Gill (2010) found that the height of turmeric plants grew when planted in raised beds, as did Nicoletto *et al.* (2016) with 7 different species of vegetables, including green beans, rocket salad, zucchini, lettuce, variegated-leaved Italian chicory, long-stemmed Italian chicory, and chard. Anand *et al.* (2016) found the same thing with ashwagandha.

Effect of mulching: As regard to mulches (M), (Table 2) the minimum days to 50% flowering (28.79) were observed in M_2 (silver/black polythene mulch) which was statistically at par (29.28 days) with M_1 (black polythene mulch) and late flowering (35.79) was recorded in M_3 (no NAA application). M_2 also had the greatest height of plants (71.08 cm), largest fruit in length (6.86 cm), largest fruit in width (5.96 cm), greatest fruit weight (48.90 g), the greatest number of fruits (24.32), yield/plot (49.93 kg), and yield/hectare (352.22 q). The M3 variety had the highest minimum days to 50% blooming, plant height, fruit length, fruit width, fruit weight, fruits/plant, plot yield, and hectare yield, with values of 35.79 days, 53.87 cm, 5.82 cm, 4.77 cm, 42.36 g, 20.99 fruits, 37.33 kg, and 263.33 q, respectively (unmulched plots). Silver black plastic mulch greatly improved yield as a result of fewer weeds, a warmer root zone temperature,

Table 1 Twelve treatments used in the experiment

Treatment	Treatment code	Treatment detail
T_1	$P_1M_1N_1$	Raised bed + Black polythene mulch + NAA application @15 ppm at 30 and 45 days after transplanting
T_2	$P_1M_1N_2$	Raised bed + Black polythene mulch + No NAA application
T_3	$P_1M_2N_1$	Raised bed + Double coloured polythene mulch + NAA application @15 ppm at 30 and 45 days after transplanting
T_4	$P_1M_2N_2$	Raised bed + Double coloured polythene mulch + No NAA application
T_5	$P_1M_3N_1$	Raised bed + No mulch + NAA application @15 ppm at 30 and 45 days after transplanting
T_6	$P_1M_3N_2$	Raised bed + No mulch + No NAA application
T_7	$P_2M_1N_1$	Flat-bed + Black polythene mulch + NAA application @15 ppm at 30 and 45 days after transplanting
T_8	$P_2M_1N_2$	Flat-bed + Black polythene mulch + No NAA application
T_9	$P_2M_2N_1$	Flat-bed + Double coloured polythene mulch + NAA application @15 ppm at 30 and 45 days after transplanting
T_{10}	$P_2M_2N_2$	Flat-bed + Double coloured polythene mulch + No NAA application
T_{11}	$P_2M_3N_1$	Flat-bed + No mulch + NAA application @15 ppm at 30 and 45 days after transplanting
T_{12}	$P_2M_3N_2$	Flat-bed + No mulch + No NAA application

Table 2 Effect of planting methods, mulches, and NAA levels on yield and yield contributing traits of bell pepper (2 years pooled data)

Treatment	Plant height (cm)	Days to 50% flowering	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	Number of fruits/plant	Yield (kg/plot)	Yield (q/ha)
Planting methods (P)								
P_1	66.58	30.79	6.61	5.62	46.93	23.50	46.46	327.74
P_2	63.49	31.78	6.34	5.40	46.21	22.65	44.12	311.28
CD (P=0.05)	0.69	0.45	0.09	NS	0.45	0.30	0.75	5.26
Mulches (M)								
M_1	70.15	29.28	6.74	5.81	48.45	23.91	48.62	342.96
M_2	71.08	28.79	6.86	5.96	48.90	24.32	49.93	352.22
M_3	53.87	35.79	5.82	4.77	42.36	20.99	37.33	263.33
CD (P=0.05)	0.85	0.55	0.11	0.26	0.55	0.36	0.91	6.44
NAA levels (N)								
N_1	67.23	30.26	6.73	5.71	47.21	24.03	47.83	337.45
N_2	62.83	32.31	6.22	5.31	45.94	22.11	42.75	301.56
CD (P=0.05)	0.69	0.45	0.09	0.21	0.45	0.30	0.75	5.26

CD, Critical difference; NS, Non-significant. Treatment details are given in Materials and Methods.

and more nutrient uptake by the plants (Amare and Desta 2021). Plastic mulches alter the local environment directly by reducing soil water loss and changing the surface's radiation budget (absorptivity vs. reflectivity). These determinants not only promoted higher yields but also led to a lot longer that bloomed earlier and developed more fully (Iqbal *et al.* 2020, Kusuma and Thaneshwari 2021).

Effect of NAA application: As in the case of NAA levels (Table 2), the plants which were treated with NAA @15 ppm at 30 and 45 days after transplanting (N_1) recorded minimum (30.26) days to 50 % flowering, maximum plant height (67.23 cm), fruit length (6.73 cm), fruit breadth (5.71 cm), fruit weight (47.21 cm), fruits/plant (24.03), yield/plot (47.83 kg) and yield/hectare (337.45 q). In relationship to the amount of NAA provided, the overall yield increased linearly. The findings of this study can be explained by the fact that the naphthalene acetic acid applied might have caused its effect on cell wall components, permeability through plasma membrane, action through certain co-enzymes, and induction of synthesis of specific RNA and proteins which in turn might have increased cell wall elasticity and extension (Dalai *et al.* 2015). Similarly, the plants subjected to NAA treatment were more physiologically active, allowing them to store more food material for the development of maximum

Table 3 Interaction effect of planting methods, mulches, and NAA levels on yield and yield contributing traits of bell pepper (2 years pooled data)

Treatment	Plant height (cm)	Days to 50% flowering	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	Number of fruits/plant	Yield (kg/plot)	Yield (q/ha)
T_1	71.81	27.52	7.18	6.21	48.80	25.42	52.08	367.41
T_2	69.62	29.70	6.55	5.70	48.34	23.39	47.32	333.83
T_3	73.96	26.89	7.29	6.31	50.06	25.98	54.53	384.69
T_4	70.20	29.79	6.70	5.85	48.56	23.55	47.95	338.27
T_5	63.86	34.52	6.12	4.91	43.56	21.90	40.11	282.96
T_6	50.01	36.32	5.81	4.75	42.25	20.75	36.75	259.26
T_7	70.77	28.67	6.87	6.03	48.96	24.51	50.40	355.56
T_8	68.39	31.23	6.36	5.28	47.69	22.32	44.66	315.06
T_9	71.11	28.25	7.02	6.07	49.15	25.02	51.66	364.44
T_{10}	69.06	30.21	6.43	5.62	47.84	22.73	45.57	321.48
T_{11}	51.89	35.73	5.90	4.74	42.70	21.36	38.23	269.63
T_{12}	49.72	36.60	5.46	4.67	40.94	19.94	34.23	241.48
CD (P=0.05)	1.70	1.10	0.22	0.53	1.11	0.73	1.84	12.96

CD, Critical difference. Treatment details are given in Table 1.

flowers and fruits, and to increase water translocation, both of which contributed to an increase in fruit settings and, ultimately, a higher yield of higher-quality fruits (Ujjwal *et al.* 2018, Binbin *et al.* 2019).

Interaction effect: Yield and all yield-contributing characteristics were shown to be significantly affected by the interplay of planting methods, mulches, and NAA levels (Table 3). The tallest plants (73.96 cm) were produced in $P_1M_2N_1$ and the smallest (49.72 cm) plants were produced in $P_2M_3N_2$) (Supplementary Fig 1). Flowering times for $P_1M_2N_1$ were found to be early (26.89 days), comparable (27.52 days) to $P_1M_2N_1$ (26.60 days), and late (36.60 days) for $P_2M_3N_2$ (Supplementary Fig 2). In $P_1M_2N_1$, maximum fruit length (7.29 cm), fruit width (6.31 cm), and fruit weight (50.06 g) were seen, while lowest fruit length (5.46 cm), fruit breadth (4.67 cm), and fruit weight (40.94 cm, respectively) were observed in $P_2M_3N_2$. More number of fruits (25.98) was recorded in $P_1M_2N_1$ which was at par (25.42) with $P_1M_1N_1$ and a minimum (19.94) was recorded in $P_2M_3N_2$ (Supplementary Fig 3).

Maximum yield/plot (54.53 kg) and yield/ha (384.69 q) were recorded in $P_1M_2N_1$ and a minimum of 34.23 kg and 241.48 q, respectively, was recorded in $P_2M_3N_2$ (Supplementary Fig 4). Raised beds may reduce waterlogging and plant stress in a number of ways, including better surface drainage, reduced tillage costs, reduced oxidation of soil organic matter, and less disturbance of bio pore during ploughing (Mohammad *et al.* 2017, Velmurugan *et al.* 2018). Because the mulches prevented the soil from coming into touch with dry air, there may have been less water evaporation and moisture loss under the mulches. Mulches also reduce the force of splashes and rain, which aids in preventing soil compaction, lessening surface runoff, and increasing water penetration (Shan Jahan *et al.* 2018). These favourable conditions for plant development and subsequent higher production were the result of several factors. Sweet pepper output was enhanced by reflecting more photosynthetically active radiation (PAR) into the plant canopy, which was achieved by applying an aluminium paint coating to the mulch (Dickerson 2012).

Improvements in production and yield characteristics were seen after switching to a light-reflecting mulch surface colour, which impacted capsicum plant growth by influencing the amount and quantity of upwardly reflected light and by adjusting soil temperature (Ray and Biswasi 2016). The application of auxin causes plant height to rise, which may be explained by an increase in cellular elongation as a consequence of the cell wall's greater flexibility (Singh *et al.* 2017, Islam *et al.* 2018). Mahindre *et al.* (2018) have also shown similar things to be true in green chilli. Bell peppers planted on a raised bed with silver/black mulch and NAA @15 ppm at 30 and 45 days after transplanting had significantly higher yields than those planted in the soil.

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