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Impact of Agronomical Approaches on Growth, Yield and Economics of Bell Pepper (*Capsicum annuum* L.) var. Solan Bharpur under Mid-hills of Himachal Pradesh

Priyanka Bijalwan[1], Shilpa[2], Y.R. Shukla[3], Manish Chauhan[3]

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ABSTRACT

Background: *Capsicum annuum* L., popularly known as bell pepper, sweet pepper and shimla mirch, is a vegetable crop in the Solanaceae family. Because of its various nutritional benefits, capsicum is ranked one of the healthiest vegetables; therefore desire for this is expanding every day. Through its importance and market requirement in consideration, a study was conducted to assess the impact of planting methods, mulches and NAA treatment on bell pepper growth, yield and economics.

Methods: The study was performed at Experimental Farm of the Department of Vegetable Science, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during *Kharif* seasons of year 2017-18 and 2018-19 (two years). The experiment was laid out in arandomized block design with three replications comprising twelve treatments.

Result: Study revealed that T_3 yielded maximum (384.69 q/ha) as well as recorded maximum values of gross return (Rs. 577,035.00/-), net return Rs. 3,52,416.93/- and comparatively less B:C ratio (1:57). Meanwhile, T_1 recorded 77.80% control in weed population and have maximum (64.12%) efficiency to control emerging weeds as compared to T_{12}.

Key words: *Capsicum annuum* L., Economics, Mulching, Planting methods, Yield.

INTRODUCTION

Bell pepper (*Capsicum annuum* L.) belongs to the family solanaceae, which is one of the important vegetable crops in India and throughout the world. It is not only used as vegetable but also it occupies a maximum place in kitchen. Its importance is increasing gradually in industries. It is a high value vegetable crop which was brought to India by the Britishers in 19th century in Shimla, Himachal Pradesh and Nilgiri hills of Tamil Nadu (Greenleaf, 1986). Bell pepper is looked upon as luxury vegetable as its consumption is greater in and around the cities. The high market price is attributed to the heavy demand from urban consumers (Akinfasoye *et al.,* 2006). Himachal Pradesh is a leading supplier of bell pepper to the plains during summer and rainy season. The produce becomes off-season to the plains and fetches higher price to the vegetable growers (Joshi and Shukla, 1997). However, productivity and quality of produce is low because of fluctuating environment prevalent during its cultivation in open. Bell pepper, besides being a cash crop is also an important vegetarian food because of its high nutritional value particularly vitamin A (870 IU) and C (175 mg per 100 g of edible portion). It also contains appreciable quantity of protein, calcium, thiamine, riboflavin and niacin (Mac Gillivary, 1961). Growing capsicum in open field condition is very difficult because it is much sensitive to both biotic (disease, pest and weed) and abiotic stresses (drought, water logging, high temperature and low temperature) (Mennan *et al.,* 2020). But good cultural practices like raised bed planting, mulching and improvement in plant physiology through application of growth regulators can mitigate the stresses.

[1]Defence Institute of Bio-Energy Research, Defence Research and Development Organization, Pithoragarh-262 501, Uttarakhand, India.
[2]Department of Vegetable Science, CSK Himachal Pradesh Agriculture University, Palampur-176 062, Himachal Pradesh, India.
[3]Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan-173 230, Himachal Pradesh, India.

Corresponding Author: Priyanka Bijalwan, Defence Institute of Bio-Energy Research, Defence Research and Development Organization, Pithoragarh-262 501, Uttarakhand, India.
Email: priyankabijalwan24@gmail.com

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Raised bed technology is an adaptation of the traditional hill and furrow row cropping design. A raised bed gets warmed up more quickly in the spring, therefore, may enhance earlier growth and allowing for a longer growing season and better growing conditions (Mc Hugh *et al.,* 2009). Since peppers perform poorly in excessively wet soils, a raised bed improves drainage and helps prevent water logging in low areas or poorly drained soils (Ahmad *et al.,* 2009). Planting vegetables on raised beds can ameliorate the effects of flooding during the rainy season. Beds also

create the opportunity for mechanical weed control and improves fertilizer placement (Singh *et al.* 2002). Yields of tomatoes increased with bed height, most likely due to improved drainage and reduction of anoxic stress (Pena and Hughes, 2007). Weed population decrease over time in a raised bed that is well cared for and mulched (Berle and Westerfield, 2013).

Mulching involves placing a layer of material on the soil around the crop of interest to modify the growing environment to improve crop productivity. Mulching increased soil porosity and reduced soil compaction. Mulching reduced leaching of nutrients, reduced weed problems, reduced evaporation of soil water and increased water use efficiency. It helps to maintain optimum soil moisture and promoted excellent crop growth throughout the growing season. Moreover, mulching increased growth and fruit yield through modification of the crop growing environment by reducing weed infestation, soil moisture depletion and ameliorating soil temperature (Awodoyin *et al.,* 2007).

Among physiological factors, hormonal imbalance in the plant is very important which decides extent of flower and fruit drop under unfavorable conditions (Singh and Lal, 1995). The metabolism of auxins and growth promoters generate the energy-rich phosphate and precursors of metabolic processes, which may be the factors in the initiation of enhanced growth processes. The increased growth and delayed senescence in turn, favors increase in yield as most of the assimilates were translocated from the source to the sink under a stimulated environment (Basu chaudhari, 2016). Greater yield through improved cultural and physiological practices results in greater yield which provide greater returns to the farmers.

Therefore, the objective of this study was conducted to compare the effect of different planting techniques, mulching and NAA application on the growth, fruit yield, weed population and economics of bell pepper.

MATERIALS AND METHODS

The experiment was performed at Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh), Vegetable Experimental Farm [35°5′N latitude and 77°11′E longitude at an elevation of 1270 m (above MSL)] in the year 2017-18 and 2018-19 during *Kharif* season. Bell pepper cultivar "Solan Bharpur" was taken as experimental material. The experiment was laid out in Randomized block design with three replications. There were 12 treatments *i.e.*, T_1: Raised bed+Black polythene mulch +NAA application @ 15 ppm at 30 and 45 day after transplanting, T_2: Raised bed+Black polythene mulch+No NAA application, T_3: Raised bed+silver polythene mulch+NAA application @ 15 ppm at 30 and 45 day after transplanting, T_4: Raised bed+silver polythene mulch + No NAA application, T_5: Raised bed+No mulch+NAA application @ 15 ppm at 30 and 45 day after transplanting, T_6: Raised bed+No mulch+No NAA application, T_7: Flat bed+Black polythene mulch+NAA application @ 15 ppm at 30 and 45 day after transplanting, T_8: Flat bed+Black polythene mulch+No NAA application, T_9: Flat bed+silver polythene mulch+NAA application @ 15 ppm at 30 and 45 day after transplanting, T_{10}: Flat bed+silver polythene mulch+No NAA application, T_{11}: Flat bed+No mulch+NAA application @ 15 ppm at 30 and 45 day after transplanting and T_{12}: control. The height of raised beds were 15 cm and each bed was separated at a 45 cm distance. Mulches of 50 (200 gauge thickness) were used in plots based on the treatment combinations.

Weed count

WC data were collected from each plot with the help of a quadrate of 1×1 m (1 m^2). For this, the quadrate was placed randomly in each plot and the total number of weeds growing within the quadrate was counted.

Weed control efficiency (%)

WCE was calculated at harvest as per the formula given below (Kondap and Upadhyay, 1985):

$$WCE = \frac{DMC - DMT}{DMC} \times 100$$

Where,
WCE= Weed control efficiency (per cent).
DMC= Dry matter production of weeds in control (weedy check) plots.

Economic analysis of treatments

After taking into consideration the fixed and variable inputs and their corresponding rates, the cost incurred on each treatment was worked out. Gross returns were computed for each treatment based on market prices of the produce and net returns were then computed by deducting the cost incurred from the gross returns of the particular treatment later on the benefit cost ratio (B:C) was calculated for each treatment as per formula given below:

$$B:C \text{ ratio} = \frac{\text{Net return (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

Statistical analysis

ANOVA was used to determine the differences between the sixteen treatments. Duncan's multiple range test (DMRT) was used to separate variances in treatment means, followed by (least significant difference) (LSD) as a post hoc test using SPSS software (11.5 version).

RESULTS AND DISCUSSION

Growth and yield parameters

Results showed that the combination of raised bed + silver/ black mulch+NAA application @ 15 ppm (T_3) performed significantly best for all the yield and its attributing traits over control treatment (T_{12}) (Table 1). 48.75% and 70.26% increment in plant height and number of branches per plant respectively was noted in $P_1M_2N_1$ as compared to control

Table 1: Effect of different agro-techniques on growth, yield, weeds and economics of bell pepper.

Traits / Treatments	Plant height (cm)	No. of branches per plant	Days to 50 flowering	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	No. of fruits per plant	Yield per plant (kg)	Yield per hectare (q)	Weed count	Weed control efficiency (%)
$P_1M_1N_1$ (T_1)	71.81±0.28^{b}	7.45±0.10^{b}	27.52±0.28^{ab}	7.18±0.02^{ab}	6.21±0.31^{ab}	48.81±0.64^{bcd}	25.42±0.38^{ab}	1.24±0.04^{b}	367.41±9.71^{b}	270.33±39.34^{a}	64.12 (53.20)±0.98^{a}
$P_1M_1N_2$ (T_2)	69.62±1.02^{cde}	6.69±0.03^{d}	29.70±0.28^{cd}	6.55±0.04^{ef}	5.71±0.36^{bcd}	48.35±0.56^{bcd}	23.39±0.30^{d}	1.13±0.02^{cd}	333.83±5.20^{d}	285.17±46.96^{ab}	63.36 (52.78)±3.12^{a}
$P_1M_2N_1$ (T_3)	73.96±1.22^{a}	7.73±0.06^{a}	26.89±0.72^{a}	7.30±0.13^{a}	6.31±0.32^{a}	50.06±0.55^{a}	25.98±0.11^{a}	1.30±0.02^{a}	384.69±6.17^{a}	387.00±57.42^{c}	53.21 (46.84)±1.86^{a}
$P_1M_2N_2$ (T_4)	70.20±0.43^{bcd}	6.88±0.10^{cd}	29.80±0.33^{cd}	6.70±0.27^{de}	5.85±0.46^{abc}	48.56±0.70^{bcd}	23.56±0.44^{d}	1.14±0.01^{c}	338.27±0.85^{c}	400.00±74.05^{c}	52.33 (46.33)±1.29^{a}
$P_1M_3N_1$ (T_5)	63.86±1.76^{f}	5.72±0.20^{f}	34.52±0.51^{f}	6.12±0.06^{g}	4.91±0.13^{ef}	43.56±1.44^{e}	21.91±0.51e^{f}	0.96±0.04^{f}	282.96±11.18^{f}	1063.33±52.62^{d}	18.16 (24.57)±7.91^{bc}
$P_1M_3N_2$ (T_6)	50.02±0.97^{h}	4.76±0.23^{gh}	36.32±0.62^{g}	5.81±0.09^{h}	4.75±0.18^{ef}	42.25±0.56^{f}	20.75±0.22^{gh}	0.88±0.02^{g}	259.26±3.92^{g}	1154.17±45.83^{de}	23.67 (25.76)±18.41^{b}
$P_2M_1N_1$ (T_7)	70.77±0.75^{bcd}	7.04±0.13^{c}	28.67±0.74^{bc}	6.87±0.09^{cd}	6.03±0.28a^{bc}	48.96±0.21^{abc}	24.51±0.07^{c}	1.20±0.01^{b}	355.56±1.49^{b}	332.17±9.70^{abc}	60.53 (51.08)±0.28^{a}
$P_2M_1N_2$ (T_8)	68.39±1.55^{e}	6.39±0.12^{e}	31.23±0.43^{e}	6.36±0.03^{f}	5.29±0.23^{de}	47.69±0.22^{d}	22.32±0.62^{e}	1.07±0.02^{e}	315.06±7.00^{e}	334.33±10.97^{abc}	61.78 (51.82)±1.80^{a}
$P_2M_2N_1$ (T_9)	71.11±0.08^{bc}	7.06±0.10^{c}	28.25±0.89^{b}	7.02±0.02^{bc}	6.07±0.46^{abc}	49.15±0.46a^{b}	25.02±0.12^{bc}	1.23±0.02^{b}	364.44±5.34^{b}	381.67±27.89^{bc}	53.29 (46.89)±1.28^{a}
$P_2M_2N_2$ (T_{10})	69.06±1.19^{de}	6.65±0.07^{d}	30.21±0.71^{dc}	6.44±0.17^{f}	5.62±0.25c^{d}	47.84±0.26^{cd}	22.74±1.05^{de}	1.09±0.06^{de}	321.48±17.08^{de}	409.50±43.31^{c}	51.89 (46.08)±0.44^{a}
$P_2M_3N_1$ (T_{11})	51.89±0.26^{g}	4.81±0.24^{g}	35.74±0.95^{g}	5.90±0.11^{h}	4.74±0.27^{ef}	42.71±0.83^{ef}	21.36±0.35^{fg}	0.91±0.01^{fg}	269.63±3.92^{fg}	1217.83±107.30^{de}	8.62 (16.78)±4.15^{cd}
$P_2M_3N_2$ (T_{12})	49.72±0.30^{h}	4.54±.09^{h}	36.60±0.91^{g}	5.46±0.17^{i}	4.67±0.06^{f}	40.94±0.44^{g}	19.94±0.88^{h}	0.82±0.03^{h}	241.48±8.25^{h}	1189.67±58.50^{e}	0.00 (0.00)±0.00^{d}
LSD (P≤0.05)	1.69	0.24	0.19	0.22	0.52	1.10	0.73	0.04	12.88	79.59	9.76

*Figures in parenthesis represent angular transformation. P_1: Raised bed planting method, P_2: Flat bed planting method, M_1: Black polythene mulch, M_2: Silver/black polythene mulch, M_3: No mulch, N_1: NAA application @ 15ppm at 30 and 45 day after transplanting, N_2: No NAA application.

($P_2M_3N_2$). Similarly, earliest flowering (26.89 days) was recorded by $P_1M_2N_1$ and late (36.60 days) flowering by $P_2M_3N_2$. Greater expand in fruit length (33.70%) and fruit width (35.12%) was recorded again in $P_1M_2N_1$as in comparison with $P_2M_3N_2$. Remarkable rise in fruit weight by 3.20%, 4.32%, 6.40%, 16.49%, 16.85%, 18.10%, 18.61%, 19.22%, 19.59%, 20.05% and 22.28% was estimated in T_6, T_{11}, T_5, T_8, T_{10}, T_2, T_4, T_1, T_7, T_9 and T_3, respectively as compared to T_{12}. Likewise, in case of number of fruits per plant was increased by 4.06%, 7.12%, 9.88%, 11.94%, 14.04%, 17.30%, 18.15%, 22.92%, 25.48%, 27.48% and 30.29% in T_6, T_{11}, T_5, T_8, T_{10}, T_2, T_4, T_1, T_7, T_9 and T_3, respectively as in comparison of T_{12}. Greater increase in yield per plant by 7.32%, 10.98%, 17.07%, 30.49%, 32.93%, 37.80%, 39.02%, 46.34, 50.00%, 51.22% and 58.54% was recorded in T_6, T_{11}, T_5, T_8, T_{10}, T_2, T_4, T_1, T_7, T_9 and T_3, respectively.

Yield per hectare was rise by 7.36%, 11.66%, 17.18%, 30.47%, 33.13%, 38.24%, 40.08%, 47.24%, 50.92% and 59.30% in T_6, T_{11}, T_5, T_8, T_{10}, T_2, T_4, T_1, T_7, T_9 and T_3, respectively (Table 1). Better plant growth and development in raised beds may be because of assimilation of macro and micro nutrients as well as more developed root system caused by tillage and greater nutrient availability (Arvidson, 1999). The raised beds do not allow the soil to get compact and the plants are less damaged due to restricted cultural operations. This result in improved soil structure and control trafficking (Berle and Westerfield, 2013). Mulching enhance greater plant morphology and yield due to no weed population, better soil moisture retention, optimum root zone temperature and better nutrient availability to the plants (Verma *et al.,* 2016, Edgar *et al.*, 2016, Helaly *et al.*, 2017). There was a linear increase in total yield with the application of NAA. The results obtained in the present findings may by explained on the basis that NAA treated plants remained physiologically more active to build up sufficient food material for developing more number of flowers and fruits, ultimately leading to more fruit setting and consequently more yield of better quality fruits (Fatima and Denesh, 2014; Vandana and Varma, 2014; Kumari *et al.,* 2017; Mohammad *et al.,* 2017).

Weed count and weed control efficiency

As depicted in Table 1, $P_1M_1N_1$ (raised bed+ black polythene mulching+NAA application @ 15 ppm at 30 and 45 days after transplanting) proved to be more efficient for controlling weed population than $P_2M_3N_2$ (flat bed+no mulch+no NAA application)/control. Weed population was reduced by 77.80%, 76.58%, 72.72%, 72.55%, 68.66%, 68.22%, 67.15%, 66.37%, 12.69%, 5.23% and 2.31% in T_1, T_2, T_7, T_8, T_9, T_3, T_4, T_{10}, T_5, T_6 and T_{11}, respectively.

Similarly, the control treatment (T_{12}) has no efficiency to control weeds. Maximum (64.12%) efficiency to control weeds was recorded in T_1 (raised bed+black polythene mulching+NAA application @ 15 ppm), while minimum (8.62%) was observed in T_{11} (flat bed+no mulch+no NAA

application) (Table 1). Number of weeds emerging out in one square meter area is an important factor which is directly related to plant vigor and yield of the plant. In the present study, mulching with black polythene and raised bed planting recorded minimum number of weeds and had greater intensity to control weeds which could be due to the fact that the mulch prevented the weed seeds to germinate. It might also be due to the preventive effect of mulch on light penetration that acted as physical barrier affecting the growth of most of the annual and perennial weeds (Ram *et al.,* 2005; Mukharjee *et al.,* 2010; Asrafuzzaman *et al.,* 2011). Another reason is mulch could be that it might create partially anaerobic conditions for the survival of weed species and thus finally resulting in a very low weed population, although moisture and nutrients were available (Schonbeck and Tillage, 2011).

Economics of bell pepper production

The data pertaining to economics of different treatments have been depicted in Table 2. An examination of the data revealed that highest gross income per hectare amounting to Rs. 5,77,035.00/- was obtained in T_3 followed by Rs. 5,51,115.00/- in T_1 and Rs. 5,46,660.00/- in T_9), whereas, lowest *i.e.* Rs. 3,62,220.00/- in T_{12}. On the other hand highest cost of cultivation per hectare *i.e.* Rs. 2,24,618.07/- was obtained in T_3 followed by Rs. 2,22,928.07/- in T_4, whereas, lowest cost of cultivation (Rs. 1,47,874.66/-) was incurred in T_{12}.

Interestingly the treatment combination T_3 which yielded maximum (384.69 q/ha) also recorded maximum values of gross return (Rs. 5,77,035.00/-), net return Rs. 3,52,416.93/ -but not B:C ratio (1:57) which was highest (1:74) in T_5. The reason for increased net profit in treatment T_3 may be due to maximum marketable yield, healthy and better fruit size and higher net returns as compared to other treatments which however, recorded more B:C ratio like T_5 (1:74) and T_{11} (1:70) (Table 2). These results are in line with those of Dadeech *et al.* (2018) who also recorded maximum net returns of Rs. 139,220.00/- with highest cost benefit ratio of 1:68:1 while using silver mulch in watermelon. The present results also showed that capsicum production in general is highly dependent on labour and can be described as labour intensive business venture.

Table 2: Effect of different treatments on economics of bell pepper production.

Treatment code	Treatment details	Yield (q/ha)	*Gross return (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	B:C ratio
$T_1(P_1M_1N_1)$	Raised bed + Black mulch +NAA application	367.41	551,115.00	2,19,418.06	3,31,696.94	1:51^{abc}
$T_2(P_1M_1N_2)$	Raised bed + Black mulch +No NAA application	333.83	500,745.00	2,17,728.06	2,83,016.94	1:30^{cde}
$T_3(P_1M_2N_1)$	Raised bed + Silver/black mulch +NAA application	384.69	577,035.00	2,24,618.07	3,52,416.93	1:57^{ab}
$T_4(P_1M_2N_2)$	Raised bed + Silver/black mulch + No NAA application	338.27	507,405.00	2,22,928.07	2,84,476.93	1:28^{cde}
$T_5(P_1M_3N_1)$	Raised bed + No mulch + NAA application	282.96	424,440.00	1,55,164.66	2,69,275.34	1:74^{a}
$T_6(P_1M_3N_2)$	Raised bed + No mulch + No NAA application	259.26	388,890.00	1,53,474.66	2,35,415.34	1:53^{abc}
$T_7(P_2M_1N_1)$	Flat bed + Black mulch + NAA application	355.56	533,340.00	2,13,818.06	3,19,521.94	1:49^{abcd}
$T_8(P_2M_1N_2)$	Flat bed + Black mulch +No NAA application	315.06	472,590.00	2,12,128.06	2,60,461.94	1:23^{de}
$T_9(P_2M_2N_1)$	Flat bed + Silver/black mulch + NAA application	364.44	546,660.00	2,19,018.07	3,27,641.93	1:50^{abc}
$T_{10}(P_2M_2N_2)$	Flat bed + Silver/black mulch +No NAA application	321.48	482,220.00	2,17,328.07	2,64,891.93	1:22^{e}
$T_{11}(P_2M_3N_1)$	Flat bed + No mulch + NAA application	269.63	404,445.00	1,49,564.66	2,54,880.34	1:70^{ab}
$T_{12}(P_2M_3N_2)$	Flat bed + No mulch + No NAA application	241.48	362,220.00	1,47,874.66	2,14,345.34	1.45^{bcde}

P_1: Raised bed planting method, P_2: Flat bed planting method, M_1: Black polythene mulch, M_2: Silver/black polythene mulch, M_3: No mulch, N_1: NAA application @ 15ppm at 30 and 45 day after transplanting, N_2: No NAA application.

*The gross returns were worked out on the basis of sale price of bell Pepper Rs. 15/-kg fixed by the University.

Highest net returns of Rs. 3,52,416.93/- in T_3 in the present studies may be attributed to less expenditure on labour involved on weeding, hoeing and other cultural operations as mulch controlled maximum weeds. Similar results on the effect of mulching on seed production of bell pepper have also been shown by Verma *et al.* (2014). Increased yield, net return and B:C ratio by using raised bed technology have also been shown by Kumar *et al.* (2015) in garlic crop under irrigated condition of Uttar Pradesh.

CONCLUSION

On the basis of two year studies, it can be concluded that the T_3 (raised bed, silver mulch with NAA application @ 15 ppm at 30 and 45 days after transplanting) which yielded maximum along with maximum gross returns, net returns and B:C ratio and T_1 (raised beds+black polythene mulch+NAA application @ 15 ppm at 30 and 45 days after transplanting) which had higher efficiency to control weeds may be recommended to the farmers for higher yield and greater income.

Conflict of interest

All authors declare that they have no conflict of interest.

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