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RESEARCH NOTE

Bell pepper (*Capsicum annuum*) productivity and economics as influenced by different weed management strategies

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ABSTRACT

The effect of polythene mulches raised bed planting, and naphthalene acetic acid (NAA) application was evaluated for weed control, yield, and economics of bell pepper. The combination treatment of raised bed planting, plastic mulch and NAA recorded the lowest intensity of *Oxalis latifolia* (15%), *Amaranthus* spp. (4%), *Echinochloa crus-galli* (5 %), *Setaria* spp. (23%) and *Commelina benghalensis* (15%). The combination of raised bed planting, double-colored polythene mulch and NAA recorded the highest yield (38.9 t/ha). The combination of raised bed planting, black polythene mulch, and NAA had the lowest weed density (277 no/m^2), less weed dry biomass (119 g/m^2), and the highest weed control efficiency (66%).

Keywords: Bell Pepper, Weed Density, Weed Control Efficiency, Yield

Bell pepper (*Capsicum annuum* L.) is one of the most important vegetable crops. It belongs to the Solanaceae family and is a vegetable appreciated by consumers because of its pleasant, refreshing taste, attractive color, and special biochemical composition (Araceli Minerva *et al.* 2011). So, the demand for this vegetable is increasing very fast. Many challenges, such as biotic and abiotic stresses, have been known to reduce the quality and production of vegetable crops (Mennan *et al*. 2020). Weeds are one of the major biotic factors that harm production (Uljol *et al.* 2016). The weeds snatch up valuable and expensive inputs like nutrients and water that are otherwise intended for maximizing the potential yield and, also operate as alternative hosts for a variety of insect pests and diseases (Shehata *et al.* 2017). Uljol *et al.* (2016) reported that weeds cause 85 to 86 % fruit yield loss in bell peppers.

The crop productivity should be increased by developing an effective weed control strategy to limit the negative effects of weeds (El-Metwally *et al.* 2019). Manual weeding is costly, time-consuming, tedious, and causes root injury. In this context, plastic mulching and different planting techniques are good interventions to manage weeds. Mulch reduces weeds by acting as a physical barrier, which inhibits growth, and by its effect on shading, which inhibits weed germination and seedling growth (Rajablarijani *et al.* 2014). Plastic mulches directly impact the microclimate in the area around the plant, by altering the radiation budget and reducing soil water loss. Raised bed planting systems have several advantages, including water savings of up to 30% combined with improved water use efficiency, improvements in soil physical properties, nitrogen use efficiency, better sunlight utilization, low crop-weed completion, and ultimately an increase in crop yield (Kumar *et al.* 2010). Bahadur *et al.* (2013) reported that raised bed planting, had a greater reduction in weed biomass than flat-bed planting because in raised beds the water was only delivered in the furrows, and the surrounding region was usually dry, preventing significant weed development and less weed interference with crop growth boosts yield.

The limitations of bell pepper production in open field conditions, such as flower dropping, poor fruit set, and vulnerability to viral infections, pose a severe threat to the growth of this crop. However, growth regulators may be useful in reducing bell pepper dropping and may enhance the quantity, size, and weight of the fruit (Monir 2018). Akhter *et al.* (2018) observed that Naphthalene acetic acid is effective in increasing fruit set and is also used in reducing pre-harvest fruit drop resulting in a higher number of fruits and yield. Considering the above fact, the present experiment was done to evaluate the effect of planting methods, mulching, and NAA application on weed control and the economics of bell pepper.

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Table 1. Details of treatments used in the studies

Treatment no.	Treatment code	Treatment details
T_1	$P_1M_1N_1$	Raised bed + black polythene mulch + NAA application 15ppm 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 colored (silver/black) polythene mulch + NAA application 15ppm at 30 and 45 days after transplanting
T_4	$P_1M_2N_2$	Raised bed + double colored (silver/black) polythene mulch + No NAA application
T_5	$P_1M_3N_1$	Raised bed + no mulch + NAA application 15ppm 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 15ppm 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 colored (silver/black) polythene mulch + NAA application 15ppm at 30 and 45 days after transplanting
T_{10}	$P_2M_2N_2$	Flat-bed + double colored (silver/black) polythene mulch + No NAA application
T_{11}	$P_2M_3N_1$	Flat-bed + no mulch + NAA application15ppm at 30 and 45 days after transplanting
T_{12}	$P_2M_3N_2$	Flat-bed + no mulch + no NAA application

The field trial was undertaken in *Kharif* (summer) 2018 at the Dr. Yashwant Singh Parmar University of Horticulture and Forestry's Vegetable Experimental Farm in Nauni, Solan (Himachal Pradesh), which is located at a height of 1270 meters above mean sea level (MSL), at 3505'N latitude and 77011'E longitude. *Solan Bharpur* was selected as the experimental bell pepper cultivar. The soil at the experimental location was a sandy loam with pH 6.6, organic carbon 6.43 mg/liter, available nitrogen 317.68 kg/ha, phosphorus 21.2 kg/ha, and potassium 160.0 kg/ha. Fertilizers and farmyard manure were applied by the recommended package of practices for bell pepper (RDF: 100 N: 75 P: 55 K kg/ha). The treatments consisted of the two planting methods (raised bed and flat-bed), three mulches (black polythene, silver/black polythene, and no mulch), and two growth regulation (NAA spray 15 ppm at 30 and 45 days after transplanting and no NAA application) (**Table 1**). These 12 treatment combinations were arranged in a factorial randomized block design with three replications. Each elevated bed had a 15 cm height and there was a 45-centimeter gap between each bed. Plots were covered with 50 (200-gauge thickness) mulches as per treatment combinations and mulches were applied one week before transplanting.

The cropping season rainfall was 752.5 mm which was received mostly in August (233.8 mm). The maximum mean temperature varied from 26.7 to 30.5°C and minimum from 13.2 to 20.4°C and the maximum relative humidity recorded was 82 % and the minimum was 44 %. At sampling time, a 1x1 m quadrate was randomly placed in each plot to evaluate weed density and dry weight of various weeds. Weed dry weight was recorded by drying the weeds at 70ºC in an oven for 48 h. Weed control efficiency (%) was determined as per the standard formula. Weed intensity (%) was calculated as a specific number of weeds (**Table 2**) to the total number of weeds present in the 1 m^2 area of each plot and calculated as per the standard formula. Analysis of variance (ANOVA) for the experiment was done as per the model suggested by Panse and Sukhatme (2000).

Table 2. Different weed species were observed in the experimental field

Monocot	Dicot	Sedges
Setaria spp.	*Echinochloa crus-galli*	*Cyperus rotundus L.*
Commelina benghalensis	*Oxalis latifolia*	
	Amarantus spp.	

Effect on weeds and yield of bell pepper

The combined effect of the planting technique + mulching + NAA was significant on weeds and crop yield parameters (**Table 3**). Raised bed + black polythene mulch + NAA application 15ppm at 30 and 45 days after transplanting (T_1) recorded the lowest weed density (277/m^2) and was at par with Raised bed + Black polythene mulch + No NAA application (T_2) (286.31/m^2), T_1 recorded the lowest dry biomass of weeds (119g/m^2) which was at par with T_2 (122g/m^2), T_8 (127g/m^2), and T_7 (131g/m^2), respectively. Flat bed with no mulch and no NAA (T_{12}) recorded higher weed dry biomass (349g/m^2). T_1 recorded the highest weed control efficiency (66%) which was at par with T_2 (65%), T_8 (63%), T_7 (62%), T_9 (55%), T_{10} (54%), T_3 (55%) and T_4 (54%), whereas, T_{11} gave the lowest weed control efficiency (10 %). Growing crops on raised beds is more efficient than conventional methods in reducing weed infestation and lodging and producing higher yields (Fahong *et al*. 2004). Treatments having black polythene mulch recorded a minimum number of weed density and biomass and higher weed control efficiency as the mulch material prevented germination of weed seeds (Ashrafuzzaman *et al.* 2011).

T_3 treatment having raised bed, silver/black polythene mulch and NAA recorded the highest crop yield (38.9 t/ha), while bare soil treatment (T_{12}) had the lowest (23.2 t/ha) yield. Raised bed planting improves soil organic matter and physical aspects due to surface retention of residues and reduces soil compaction by restricting traffic to the furrows (Govaerts *et al.* 2007). The color of plastic mulches and seasonal weather have a considerable impact on the pepper plant's fruit yield (Díaz-Pérez, 2010). This impact is associated with the impact of plastic mulching on the improvement of the microclimate and root zone temperature of plants which increases activities of cell expansion and cell enlargement. Furthermore, the active involvement of the enzymes in enhancing growth and development also increased crop yield (Li *et al.* 2004). The endogenous hormonal pattern of the plant is impacted by the exogenous application of growth regulators like naphthalene acetic acid, either by supplementing inadequate levels or by interacting with their synthesis, translocation, or inactivation of existing hormone levels, which increases crop yield (Singh *et al.* 2017).

Economics of bell pepper production

The highest gross income (₹ 5,83,0710/ha) was recorded under Raised bed + Double colored (silver/black) polythene mulch + NAA application 15 ppm at 30 and 45 days after transplanting (T_3) followed by Flat-bed + Double colored (silver/black) polythene mulch + NAA application 15ppm at 30 and 45 days after transplanting (T_9) (₹ 5,39,265/ha), whereas, it was lowest (₹ 3,48,150/ha) in T_{12}. On the other hand, T_3 had the highest cost of cultivation (₹ 2,35,560/ha) followed by T_9 (₹ 2,30,566/ha) and lowest in T_{12} (₹ 1,58,363/ha). 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 (1:53) and T_{11} (1:50) (**Table 3**). Dadeech *et al.* (2018) also recorded the highest net returns while using silver mulch in watermelon. The highest net returns of ^{1} 3,48,149/ha in T_3 may be attributed to less

Table 3. Effect of different treatments on weed characters, yield and economics of bell pepper

Treatment	Weed density (no./m^2)	Weeds dry biomass (g/m^2)	Weed control efficiency (%)	Yield (kg/plot)	Yield (t/ha)	*Gross return (x10^4 `/ha)	Net return (x10^4 `/ha)	B: C ratio
T_1 ($P_1M_1N_1$)	277.7±32.58^a	119.0±7.21^a	65.8 (54.20) ±2.72^a	50.8±2.75^b	35.85±1.94^b	23.02	30.75	1.34^b
T_2 ($P_1M_1N_2$)	286.0±31.00^a	121.7±14.57^a	64.6 (53.58) ±7.58^a	47.9±0.42^c	33.78±0.30^c	22.86	27.80	1.22^c
T_3 ($P_1M_2N_1$)	387.0±57.42^b	155.7±12.34^a	55.3 (48.03) ±3.55^a	55.2±0.87^a	38.91±0.62^a	23.56	34.81	1.48^a
T_4 ($P_1M_2N_2$)	400.0±74.05^b	159.7±10.69^a	54.1 (47.36) ±3.47^a	48.6±1.28^{bc}	34.27±0.91^{bc}	23.32	28.08	1.20^c
T_5 ($P_1M_3N_1$)	1063.3±52.62^c	271.3±29.37^b	21.36 (26.42) ±14.93^{bc}	39.8±0.87^e	28.05±0.62^e	16.61	25.46	1.53^a
T_6 ($P_1M_3N_2$)	1150.0±48.59^d	253.0±62.86^b	26.7 (27.15) ±23.10^b	36.0±0.87^f	25.38±0.62^f	16.43	21.61	1.32^b
T_7 ($P_2M_1N_1$)	321.0±6.56^{ab}	130.7±2.52^a	62.3 (52.16) ±3.42^a	50.0±1.11^{bc}	35.26±0.78^{bc}	22.49	30.40	1.35^b
T_8($P_2M_1N_2$)	323.3±13.65^{ab}	127.3±10.69^a	63.4 (52.78) ±3.47^a	44.0±0.48^d	31.01±0.34^d	22.32	24.21	1.08^d
T_9 ($P_2M_2N_1$)	368.3±16.44^{ab}	155.0±8.72^a	55.4 (48.10) ±3.97^a	51.0±1.59^b	35.95±1.12^b	23.06	30.87	1.34^b
T_{10} ($P_2M_2N_2$)	411.0±42.44^b	159.3±5.13^a	54.1 (47.37) ±3.51^a	45.2±2.11^d	31.90±1.49^d	22.82	25.03	1.10^d
T_{11} ($P_2M_3N_1$)	1219.3±107.64^d	313.0±10.58^c	9.9 (17.79) ±6.59^{cd}	37.9±0.97^{ef}	26.76±0.68^{ef}	16.03	24.11	1.50^a
T_{12}($P_2M_3N_2$)	1161.3±34.27^d	349.3±38.70^c	0.0 (0.00) ±0.00^d	32.9±0.24^g	23.21±0.17^g	15.84	19.00	1.20^c
LSD (p=0.05)	76.38	40.74	12.00	2.28	1.61	-	-	0.09

*Figures in parentheses represent angular transformation

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

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 days after transplanting, N_2: No NAA application

Table 4. Effect of different treatments on weed intensity (%)

Treatment	*Oxalis latifolia* (%)	*Amaranthus* spp. (%)	*Cyperus rotundus* (%)	*Echinochloa crus-galli* (%)	*Setaria* spp. (%)	*Commelina benghalensis* (%)
T_1 ($P_1M_1N_1$)	14.7(22.5) ±0.90^a	4.2(11.8) ±0.71^a	10.1(18.50) ±0.13^a	5.2(13.20) ±0.56^a	23.1(28.72) ±0.78^a	14.8(22.64) ±0.23^a
T_2 ($P_1M_1N_2$)	24.4(29.0) ±14.91^b	4.7(12.5) ±0.17^{ab}	10.0(18.5) ±0.34^a	5.8(13.9) ±0.23^a	23.6(29.1) ±0.62^a	15.1(22.9) ±0.39^a
T_3 ($P_1M_2N_1$)	24.9(29.9) ±0.56^b	6.9(15.2) ±0.30^d	15.3(23.0) ±0.67^c	7.2(15.5) ±0.62^b	26.2(30.8) ±1.02^b	17.4(24.6) ±0.99^{bc}
T_4 ($P_1M_2N_2$)	23.6(29.1) ±0.21^b	6.8(15.1) ±0.40^d	15.0(22.8) ±0.07^c	7.0(15.3) ±0.47^b	26.4(30.9) ±1.22^b	18.0(25.1) ±0.82^c
T_5 ($P_1M_3N_1$)	53.4(47.0) ±0.41^c	18.9(25.8) ±0.37^f	55.3(48.0) ±0.76^e	12.2(20.4) ±0.62^d	41.0(39.8) ±0.27^c	27.1(31.3) ±0.72^e
T_6 ($P_1M_3N_2$)	54.0(47.3) ±0.14^c	19.1(25.9) ±0.15^f	55.2(48.0) ±1.66^e	12.0(20.3) ±0.53^d	41.5(40.1) ±0.76^c	27.2(31.4) ±0.37^e
T_7 ($P_2M_1N_1$)	15.7(23.3) ±0.42^a	5.5(13.6) ±0.81^{bc}	12.8(21.0) ±0.68^b	5.8(14.0) ±0.19^a	24.2(29.4) ±0.99^a	16.6(24.0) ±0.24^b
T_8($P_2M_1N_2$)	14.9(22.7) ±0.94^a	6.0(14.1) ±0.49^{cd}	12.8(21.0) ±0.74^b	5.6(13.7) ±0.33^a	24.0(29.3) ±0.51^a	16.9(24.2) ±0.04^{bc}
T_9 ($P_2M_2N_1$)	28.2(32.1) ±0.59^b	9.4(17.8) ±0.48^e	21.8(27.8) ±1.38^d	8.2(16.6) ±0.35^c	26.6(31.1) ±0.54^b	19.9(26.5) ±0.55^d
T_{10} ($P_2M_2N_2$)	28.5(32.2) ±0.55^b	9.6(18.0) ±0.51^e	21.8(27.6) ±1.32^d	8.2(16.6) ±0.84^c	27.0(31.3) ±0.17^b	20.1(26.7) ±0.76^d
T_{11} ($P_2M_3N_1$)	63.5(52.8) ±1.98^d	21.4(27.6) ±0.90^g	63.0(52.2) ±0.72^f	13.8(21.8) ±0.44^e	47.5(43.6) ±0.76^d	32.5(34.7) ±0.76^f
T_{12}($P_2M_3N_2$)	63.3(52.7) ±0.17^d	21.5(27.6) ±0.96^g	63.3(52.3) ±0.74^f	13.8(21.8) ±0.27^e	47.9(43.8) ±0.17^d	32.5(34.7) ±1.01^f
LSD (p=0.05)	7.58	0.57	1.06	0.84	0.83	1.00

*Figures in parentheses 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 days after transplanting, N_2: No NAA application expenditure on the labor involved in weeding, hoeing, and other cultural operations such as mulch-controlled 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 and, net returns by using raised bed technology have also been shown by Kumar *et al*. (2015) in garlic crops under irrigated conditions in Uttar Pradesh.

Effect on weed intensity (%)

A combination of planting techniques, mulching, and NAA spray showed significant results for weed intensity (**Table 4**). T_1 recorded lower intensity of *Oxalis latifolia* (14.7%) which was at par with T_8 (14.9%) and T_7 (15.7%) while higher was noted in T_{11} (63.50%). Similarly, lower weed intensity of *Amaranthus* spp. (4.2%), *Cyperus rotundus* (10%), *Echinochloa crus-galli* (5.2%), and *Setaria* spp. (23.1%) was observed in T_1 and higher in T_{12} *i.e*., (21.5%), (63.3%), (13.8%) and (47.9%), respectively. T_1 recorded less intensity of *Commelina benghalensis* (14.8%) as compared to T_{11} (32.5%). Significantly higher weed populations in the unmulched than mulched plots could be more weed seeds spread better weed growth in the absence of mulch (Negi 2015) and the preventive effect of mulch on light penetration that acted as a physical barrier affecting the growth of most of the annual and perennial weeds (Mukherjee *et al*. 2010).

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