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Effect of Soil Improvement Practices and NAA Application on Yield and *Phytophthora* Diseases of Sweet Pepper (*Capsicum annuum* L.)

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Abstract

Capsicum is a significant genus for its nutritional, economic, and cultural values. Besides that, Phytophthora capsici causes a significant decline in yield. So, a study was carried out to determine the response of bell pepper crop yield and incidence of Phytophthora disease to two planting methods, three mulch levels, and two NAA levels. Results indicated that planting methods, mulch materials, and NAA levels significantly influenced bell pepper disease(s) and yield. Plants grown on raised beds had minimum severity of disease and higher yield. Black polythene mulch responded best for less disease severity of leaf blight and incidence of collar rot, whereas, silver/black mulch showed significantly least incidence of fruit rot and higher yield. It also recorded lower disease infection and greater yield as compared to no NAA application. As for the consortium, the minimum severity of leaf blight (1.13 %), yield per plot (54.53 kg) and yield per hectare (384.69 q) were noticed under raised bed planting coupled with silver/black mulch and NAA application @ 15 ppm at 30 and 45 days after transplanting.

Keywords: *Capsicum annuum, disease, mulch, NAA, planting, yield*

Introduction

Capsicum annuum L. belongs to the family Solanaceae and has attained an important status and special significance in the mid-hills of Himachal Pradesh where it is cultivated as an off-season crop during the summer months. Bell pepper is a high-value crop worldwide in recent years and occupies a proud place among warm-season vegetables in international cuisine because of its delicacy, pleasant flavour, and great nutrient content [1]. The significant problems caused by soil-borne pathogens in crop production worldwide include reduced crop performance, decreased yield, and higher production costs [2].

The first description of *Phytophthora capsici* was given by L H Leonian as a pathogen of chili pepper in the year 1920 [3]. *P. capsici* causes foliar blightning, fruit rot, collar rot, damping-off, and wilting of susceptible hosts like cucurbits and peppers [4] and causes great economic losses. Management of *P. capsici* disease is limited due to the long-term survival of the pathogen as oospores in the soil [5], a wide host range [6], a moment of the pathogen in surface water used for irrigation and so many [7].

Rainfall is the most influential environmental factor affecting the incidence and progress of this disease, and flowing water appears necessary for the detachment and spread of sporangia [8]. When heavy rainfall occurs, disease severity may develop even in well-drained soil as pathogens dispersed by wind-driven rain, and the flow of runoff water may distribute inoculums down rows [9 &4], especially in flat beds. Crop plantation on the raised surface can prevent soil moisture accumulation at the plants' base. Covering the raised beds with plastic mulch covers is desirable to increase yield by reducing the crop loss by *Phytophthora capsici* [10 &11]. Water management has been reported as an important strategy in managing soil-borne diseases like *Phytophthora* [12].

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As the Bell pepper crop is sensitive to water logging, in the such case raised beds offer the potential to reduce water logging stress through improved surface drainage, and check the spread of soil-borne diseases like Phytophthora [13-15]. Soil drainage by preparing raised surfaces and furrows should be designed to prevent the formation of standing water; this will help to reduce the amount and duration of contact between fruit and wet soil [16].

The use of mulching is another way to restrict the spread of *P. capsici* infection. The word mulch has been derived from the German word *molsch* means "easy to decay," and mulches have widely been used for vegetable production since ancient times [17]. Mulching minimizes soil moisture losses [18-21], water runoff, weed population, nutrient loss, and soil erosion and enhances crop yield [22 &23], improving the infiltration capacity of the soil, and soil temperature regulation. Plastic mulch either it is black or silver mulch might help reduce water splashing and thus turn the spread of *Phytophthora* inoculums [16]. Mulches act as the beating action of raindrops that carry zoospores of *Phytophthora* or other soil-borne diseases. These spores attach themselves to foliage, lower fruits, and shoots of the plant which causes secondary infection of disease [24]. Mulches help in nitrifying many beneficial microorganisms which compete with the pathogenic spores or sometimes release chemicals for the inhibition of pathogens [25].

NAA is a synthetic plant hormone in the auxin family, which has been used for a long time to improve the quality and quantity of fruits and vegetables [26]. The application of NAA increases most of the growth and yield characteristics [27]. Metabolism of auxin generates the energy-rich phosphate and precursor of many metabolic processes, which leads to growth initiation, and such condition favours increased yield as most of the assimilates translocated from source to sink under a favourable environment [28]. NAA also plays a great role in the suppression of diseases like *Phytophthora*, it reduces mycelium growth rate [29]. Circulation of NAA is very slow in plant tissues than other auxins, and the flux transport rate of NAA is also slow. So, when NAA is applied exogenously on plant tissues, it accumulates in the upper layer of cells where it initiates resistance against the fungus for a short time period [30]. In considering the aforementioned, a research study was carried out to assess the impact of various soil improvement strategies on bell pepper yield and phytophthora disease.

Materials and Methods

Field experiments to determine the effect of soil improvement practices and Naphthalene acetic acid on yield and *Phytophthora* diseases of bell pepper were conducted in a randomized block design (factorial) during *Khraif* seasons (April to August) of 2017-18 and 2018-19 at Experimental Farm of the Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP.

The experiment comprised of two planting methods *viz.*, P_1 (raised bed planting method) and P_2 (flat bed planting method), three levels of mulch materials *viz.*, M_1 (black polythene mulch), M_2 (silver/black polythene mulch) and M_3 (no mulch) and two NAA levels *viz.*, N_1 (application of NAA @ 15ppm at 30 and 45 days after transplanting) and N_2 (no NAA application) (Table 1). Thus, there were 12 treatment combinations in all replicated thrice. The height of the raised beds was 15 cm above the ground level and two beds were separated by 45 cm distance. Seedlings were transplanted on well-prepared plots in April 2017 and 2018 at a spacing of 60×45 cm in a plot having dimensions of 1.20×9.45 m, accommodating 42 plants per plot. Mulches of 50μ (200 gauge thickness) were applied in plots according to the treatment combinations. After that holes were made in the mulch as per the recommended spacing of the plants.

Bell pepper cultivar "Solan Bharpur" was used in the present study. This cultivar was released by the Department of Vegetable Science, Dr. YSP UHF Nauni, Solan. It is a high-yielding open-pollinated variety which is a selection from segregating populations having four-lobed fruits. 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.

Results and Discussion

It is clear from the data presented in Table 2 that there was a significant effect of different planting methods, mulches, and NAA levels on diseases and the yield of sweet pepper.

Planting methods

Lower leaf blight severity (2.52 %), the incidence

Table 1. Detail of treatments used in the experiment

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 + silver polythene mulch + NAA application @ 15ppm at 30 and 45 days after transplanting
T_4	$P_1M_2N_2$	Raised bed + silver colored 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 + silver colored polythene mulch + NAA application @ 15ppm at 30 and 45 days after transplanting
T_{10}	$P_2M_2N_2$	Flat bed + silver colored polythene mulch + No NAA application
T_{11}	$P_2M_3N_1$	Flat bed + No mulch + NAA application @ 15ppm at 30 and 45 days after transplanting
T_{12}	$P_2M_3N_2$	Flat bed + No mulch + No NAA application (control)

Table 2. Effect of planting methods, mulches and NAA levels on diseases and yield of bell pepper

Treatment	Severity of leaf blight (%)	Incidence of collar rot (%)	Incidence of fruit rot (%)	Yield per plot (kg)	Yield per hectare (q)
Planting methods (P)					
P_1	2.52 (1.50)	5.43 (2.24)	4.85 (2.08)	46.46	327.74
P_2	3.68 (1.81)	6.65 (2.45)	6.27 (2.38)	44.12	311.28
$CD_{0.05}$	**0.06**	**0.06**	**0.05**	**0.75**	**5.26**
Mulches (M)					
M_1	1.55 (1.24)	2.86 (1.69)	2.93 (1.70)	48.62	342.96
M_2	1.63 (1.27)	4.08 (2.02)	2.89 (1.69)	49.93	352.22
M_3	6.13 (2.46)	11.18 (3.34)	10.85 (3.29)	37.33	263.33
$CD_{0.05}$	**0.07**	**0.07**	**0.06**	**0.91**	**6.44**
NAA levels (N)					
N_1	2.98 (1.62)	5.86 (2.31)	5.40 (2.19)	47.83	337.45
N_2	3.23 (1.69)	6.23 (3.39)	5.72 (2.27)	42.75	301.56
$CD_{0.05}$	**0.06**	**0.06**	**0.05**	**0.75**	**5.26**

*Figures in parenthesis represent square root transformation
P_1: Raised bed planting method, P_2: Flatbed 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

of collar rot (5.43 %), and fruit rot (4.85 %) were recorded in those plants which were grown on raised beds, whereas, the plants which were grown on flat beds had higher severity of leaf blight (3.68 %), the incidence of collar rot (6.65 %) and fruit rot (6.27 %) caused by *Phytophthora capsici*. Similar plots observed higher increased yield per plot (46.46 kg) and per hectare (327.74 q). *Phytophthora* blight, root rot, and fruit rot are very serious problems in solanaceous vegetables. The main source of pathogens is infested soil. Pathogen survives in contaminated soil for many years [31]. Planting into raised beds can prevent soil moisture accumulation at the base of the plants. Sharma *et al.* [32] concluded that raised bed planting + *Eucalyptus globulus* (10 %) + Bavistin (0.1 %) was the most effective and significantly best treatment with the least disease incidence and maximum disease control in capsicum crop due to proper soil drainage

Table 3. Interaction effect of planting methods, mulches and NAA levels on disease and yield of bell pepper

Interaction	Severity of leaf blight (%)	Incidence of collar rot (%)	Incidence of fruit rot (%)	Yield per plot (kg)	Yield per hectare (q)
$P_1M_1N_1$	1.19 (1.09)	2.75 (1.66)	2.20 (1.48)	52.08	367.41
$P_1M_1N_2$	1.26 (1.12)	2.91 (1.70)	2.83 (1.68)	47.32	333.83
$P_1M_2N_1$	1.13 (1.06)	3.56 (1.89)	2.27 (1.51)	54.53	384.69
$P_1M_2N_2$	1.70 (1.30)	3.97 (1.99)	2.55 (1.59)	47.95	338.27
$P_1M_3N_1$	4.87 (2.21)	9.45 (3.07)	9.56 (3.09)	40.11	282.96
$P_1M_3N_2$	5.01 (2.24)	9.95 (3.15)	9.67 (3.11)	36.75	259.26
$P_2M_1N_1$	1.90 (1.38)	2.64 (1.62)	3.27 (1.81)	50.40	355.56
$P_2M_1N_2$	1.84 (1.35)	3.14 (1.77)	3.43 (1.85)	44.66	315.06
$P_2M_2N_1$	1.77 (1.33)	4.24 (2.06)	3.25 (1.80)	51.66	364.44
$P_2M_2N_2$	1.93 (1.39)	4.57 (2.14)	3.51 (1.87)	45.57	321.48
$P_2M_3N_1$	7.02 (2.65)	12.51 (3.54)	11.86 (3.44)	38.23	269.63
$P_2M_3N_2$	7.64 (2.76)	12.81 (3.58)	12.31 (3.51)	34.23	241.48
$CD_{0.05}$	**0.14**	**0.14**	**0.12**	**1.84**	**12.96**

*Figures in parenthesis represent square root transformation

P_1: Raised bed planting method, P_2: Flatbed 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

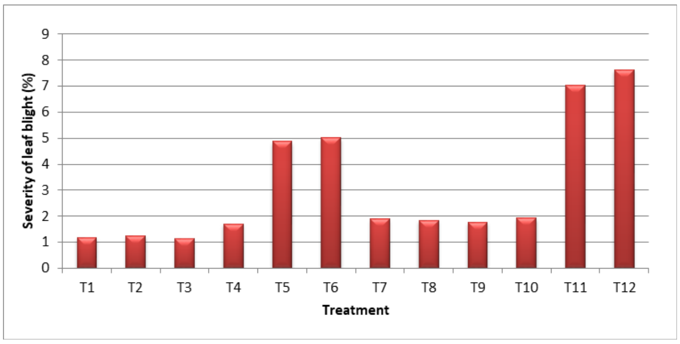

Figure 1. Interaction effect on severity of leaf blight (%) in bell pepper

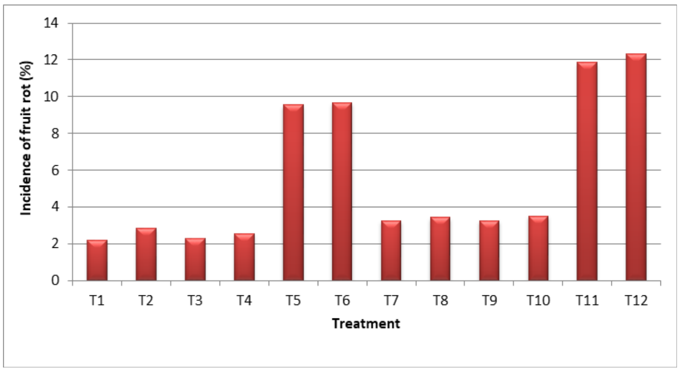

Figure 3. Interaction effect on incidence of fruit rot (%) in bell pepper

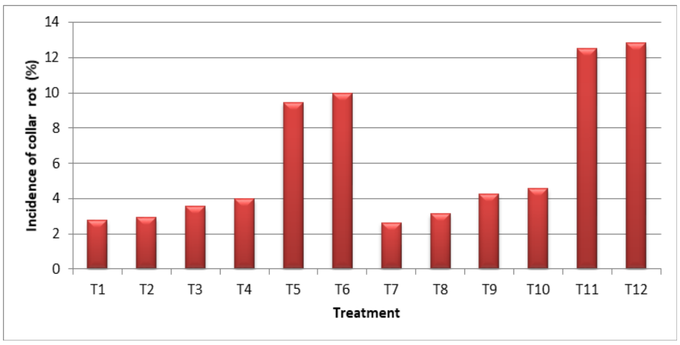

Figure 2. Interaction effect on incidence of collar rot (%) in bell p

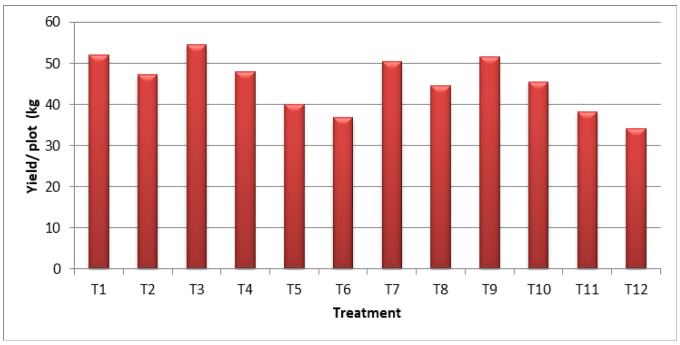

Figure 4. Interaction effect on yield/plot (kg) of bell pepper

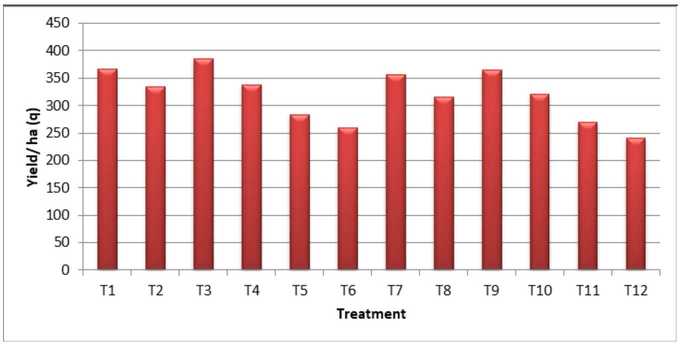

Figure 5. Interaction effect on yield/ha (q) of bell pepper

in raised beds. Increased yield in raised bed planting could be due to improved crop growth due to better soil conditions, minimum tillage, and improved soil structure through increased organic matter level and root activity of pepper and pea [33-35]. Also, there was minimum compaction of the soil which resulted in reduced mechanical inputs and better aeration.

Mulch material

As regards mulches (Table 2), the minimum severity of leaf blight (1.55 %) was recorded in the plants M_1 which was statistically at par (1.63 %) with M_2 and the maximum (6.13 %) severity was recorded in M_3. Similarly, a lower (2.86 %) incidence of collar rot was recorded when the plants were grown using black mulch while a maximum (11.18 %) was recorded when the plants were grown without mulch. In the case of fruit rot, less (2.89 %) incidence of fruit rot was observed in M_2, which was statistically at par (2.93 %) with M_1 while more (10.85 %) incidence was calculated in no mulch plots. Silver mulched plots also produced increased yield per plot (49.93 kg) and yield per hectare (352.22 q), whereas, decreased yield (37.33 kg per plot) and (263.33 quintals per ha) was produced by the plants grown on bare soil. Plastic mulching reduces disease by preventing the formation of a bridge of dead tissues between the soil and the plants. It also reduces the weed population which leads to the starvation of fungus by elimination of weed hosts [36]. Studies conducted by Ashrafuzzaman *et al.* [37] and Verma *et al.* [38] revealed that the use of silver black plastic mulch significantly increased yield due to minimum weeds, better soil moisture retention, optimum root zone temperature, and better nutrient availability to the plants. Higher marketable fruit yield from mulched plots than the plants produced on bare soil was also reported in bell pepper [39 &40]. This difference could be attributed to mineral nutrient uptake in the mulched plots through improved root temperature.

NAA levels

In the case of NAA levels (Table 2), the plants which were sprayed with Naphthalene acetic acid had minimum severity of leaf blight, the incidence of collar rot and fruit rot i.e., (2.98 %), (5.86 %) and (5.40 %), respectively, while the plants with no NAA application recorded maximum (3.23 %) severity of leaf blight, collar rot (6.23 %) and fruit rot (5.72 %) incidence. Similarly, superior yield per plot (47.83 kg) and per hectare (337.45 q) was recorded in N_1, whereas, the lowest yield per plot (42.75 kg) and per hectare (301.56 quintals) was recorded in N_2. There is ample evidence that NAA is a potential antifungal agent [41-43], however, the role of auxin in the growth and development of fungi has not yet been clearly elucidated. NAA-treated plants remained physiologically more active to build up sufficient food material for developing a greater number of flowers and fruits, ultimately leading to more fruit setting and consequently more yield of better-quality fruits in chilli and sweet pepper [44-46]. Basuchaudhuri [26] noted a significant effect of Planofix (NAA) on plant height, number of fruiting branches, and yield probably due to functions of NAA like the stimulation of cell division, cell elongation, elongation of shoots, photosynthesis, RNA synthesis, membrane permeability, and water uptake in many physiological processes.

Consortium effect

The interaction of P, M, and N was found to be significant for all the diseases and yield characters (Table 3). The minimum severity of leaf blight (1.13 %) was recorded in T_3, which was statistically at par (1.19 %) and (1.26 %) with T_1 and T_2, respectively (Fig. 1). Similarly lower incidence of collar rot (2.64 %) was recorded in T_7, which was at par (2.75 %) and (2.91%) with T_1 and T_2, respectively (Fig. 2). Lower incidence of fruit rot (2.20 %) was recorded in $P_1M_1N_1$ (Fig. 3). This was at par (2.27 %) and (2.55 5) with $P_1M_2N_1$ and $P_1M_2N_2$ respectively. Control plots ($P_2M_3N_2$) recorded more severity of leaf blight (7.64 %), the incidence of collar rot (12.81 %), and fruit rot (12.31 %). *Phytophthora* is activated only in waterlogged soils. Wet soil triggers oospores to germinate and produce sporangia that release zoospores within thirty minutes. Zoospores are attracted to roots and infect root hairs. Sporangia produced above ground are splashed onto fruit and other plants in

the field. When sporangia land on plant tissues, the disease starts quickly [47 &48]. Therefore, optimizing vertical drainage should effectively reduce the period of soil saturation and subsequent damage due to disease [49]. So, raised beds are a better option to reduce the harmful effect of soil-borne diseases like *Phytophthora*. Planting with mulches can reduce the splashing of *P. capsici*-infested soil onto plant material and be shown to lower disease incidence and pathogen spread as compared to bare soil [50 &16].
Raised bed planting + silver mulch + NAA application produced excellent yield (54.53 kg/ plot) and (384.69 q/hectare), whereas, lower yield per plot (34.23 kg) and per hectare (241.48 q) was produced by $P_2M_3N_2$ (Fig. 4 and 5). According to Islam *et al.* [51] planting the crop in raised bed create better drainage, conserved moisture during the dry season, greater soil depth, adequate soil moisture throughout the year, and increased water level above field capacity which are probable factors responsible for increased yield. Mulch surface colour that reflects light affected the growth of bell pepper plants by influencing the amount and quantity of upwardly reflected light in addition to modification of soil temperature [52&53]. Mohammad *et al.* [54] and Kumari *et al.* [55] reported the significant effect of NAA on plant processes like vascular tissue differentiation, root initiation, apical dominance, fruit set, and flowering. All these processes are directly or indirectly responsible for an increase in yield and yield contributing characters.
Based on the findings from this research, growing bell peppers in a raised bed with silver/black mulch and NAA @ 15 ppm at 30 and 45-days post-transplantation is the preferred way of improving crop yield and minimizing the incidence of *Phytophthora* disease.

Conflict of Interest: The authors declare that no conflict of interest exists

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