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Impact of Agronomic Practices on Soil Parameters in Broccoli under Agro-climatic Zone-II of Himachal Pradesh

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Abstract: Field experiment with thirteen treatments comprised of three dates of transplanting, two mulching and two irrigation levels was laid out in 2021-22. The use of black poly mulch in main, mid, and late season transplanting with irrigation and rainfed conditions had a significant impact on organic carbon content, DTPA extractable micronutrient cations, and available boron content of the soil in broccoli. The maximum organic carbon was recorded in mid-season transplanted broccoli with mulch in rainfed conditions. DTPA extractable Cu, Zn, Mn and available boron was maximum under late season transplanted broccoli with mulch in irrigated conditions. The DTPA extractable Fe was in main season transplanted broccoli with mulch in rainfed conditions. However, treatments without mulch in main, mid and late season transplanting with irrigation and rainfed conditions significantly affected the pH, EC, available N content in soil. Maximum pH was in control and also in late season transplanted broccoli without mulch in rainfed conditions. The maximum EC was also recorded in late season transplanted broccoli without mulch in rainfed conditions. The significant highest available N was recorded in main season transplanted broccoli without mulch in rainfed conditions. However, the effect of different transplanting, mulching and irrigation application on the available phosphorus and potassium content of soil remained non-significant. It is concluded that mulching improved soil parameters and provides suitable condition for broccoli in agro-climatic zone-II of Himachal Pradesh.

Keywords: Mulching, Transplanting, Broccoli, Irrigation, Soil parameters

The farmers are heavily reliant on rainfall and are unable to produce yields of higher quality when the soil is not provided with sufficient irrigation. The main obstacles to boosting agricultural productivity are the uneven distribution of rains with frequent dry spells in the winter, the occurrence of sub-optimal soil temperatures, and the poor retentivity of hill soils for water and nutrients. Low soil temperature, which has a more significant impact on seed germination, seedling emergence, and early plant growth than on later stages of growth, is one of the other important variables that have slowed the growth and productivity of winter-season crops in the mid-hills. To overcome these restrictions, proper soil and water management has required in-situ moisture conservation through the use of mulches. The practice of mulching has the potential to significantly boost crop growth, yield and net return by reducing soil warmth, increasing the availability of both applied and native nutrients, and satisfying the partial irrigation water demand. Mulch can be made from a variety of materials, including grass, wood, sand, plastic film, wheat straw, rice straw and rice husk (Uwah and Iwo 2011). Khurshid et al (2006) observed that mulching can greatly enhance the physico-chemical qualities of soil, optimise the use of water and nutrients, control weed development, promote infiltration and decrease water loss due to excessive evapotranspiration. Sinkeviciene et al (2009) noted that organic mulches have positive effects on soil characteristics, which enhance soil quality and production. Crop residue mulching improve water retention and soil organic carbon at the surface layer (Saroa and Lal 2003). Youssef et al (2021) revealed that organic mulch directly alters the soil's biological properties and fertility in addition to increasing yield, soil water content and minimum soil temperature. The availability and uptake of nutrients by plants were both increased by increased soil water storage as a result of mulching (Tan et al 2009). By increasing the agronomic value of soil physical qualities, straw mulch has also been proven to dramatically improve soil-water-crop connections.

Global interest in irrigation development and agricultural water management is rising as a result of worries about a lack of water owing to a changing and unpredictable environment. The lengthy droughts and irregular rainfall patterns that hinder the growth of crops have been brought on by global warming. Smallholder farmers have over time adapted a variety of traditional agricultural methods through the use of local knowledge and adaptations that are best suited to their local conditions, which are primarily characterised by the scarcity of water supplies. Under these water-strapped circumstances, there are a number of variables that can affect crop productivity. Mulching is one of the most suitable water conservation techniques (Khurshid et al 2006). Thus, for crop production in dry and semi-arid environments, a combination of suitable irrigation, mulching, and transplanting provides an effective soil and water conservation approach (Jia et al 2018).

Broccoli first originated in the Mediterranean and East-Asian regions. As per final estimate of 2022-23, the area under broccoli and cauliflower in Himachal Pradesh is 5.55 thousand hectare with production of 123.07 thousand metric tonnes. In India, area under this cole crop is 491.49 thousand hectare with production of 9548.01 thousand metric tonnes (Anonymous 2024). Temperatures between 17°C and 23°C are ideal for broccoli growth on a regular basis. Broccoli is the most productive type for boosting farmer income in high-altitude and tribal locations (Sivakumar et al 2022). This study was conducted by adjusting transplanting dates, mulching, and irrigation application in the mid-hill zone agro-climatic zone-II of Himachal Pradesh in order to produce broccoli commercially, which is an emerging challenge in the changing environmental conditions that make it difficult for farmers to cultivate broccoli appropriately.

Table 1. Treatment details

Sr. No.	Treatments
T_1	Control
T_2	Main season transplanting + Mulch + Irrigation
T_3	Main season transplanting + Mulch + Rainfed
T_4	Mid-season transplanting + Mulch + Irrigation
T_5	Mid-season transplanting + Mulch + Rainfed
T_6	Late season transplanting + Mulch + Irrigation
T_7	Late season transplanting + Mulch + Rainfed
T_8	Main season transplanting + No Mulch + Irrigation
T_9	Main season transplanting + No Mulch + Rainfed
T_{10}	Mid-season transplanting + No Mulch + Irrigation
T_{11}	Mid-season transplanting + No Mulch + Rainfed
T_{12}	Late season transplanting + No Mulch + Irrigation
T_{13}	Late season transplanting + No Mulch + Rainfed

MATERIAL AND METHODS

The present field experiment on broccoli crop was conducted at Experimental Farm of Department of Environmental Science, College of Forestry, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India during the winter season of 2021-22. The climate of the area is sub-tropical to sub-temperate and sub-humid characterized by cold winters and experiences distinguished major seasons in the year. The area is situated at 30.86°N latitude and 77.17°E longitude an altitude of 1275m above the mean sea level. The annual normal of maximum and minimum temperature, relative humidity, and rainfall of the area is 25.3°C, 11.4°C, 61 per cent, and 111.9 cm, respectively.

Experimental methodology: The soils of the experimental field were deep brown in color with a loam texture. The Broccoli (*Brassica oleracea* var italica) crop was sown in the main season, mid-season, and late season in the nursery on 12th September 2021, 02nd October 2021, and 23rd October 2021, respectively. Farm Yard Manure was applied 10 days before transplanting at the rate of 10 kg per bed. FYM was applied as per the package of practices for vegetable crops, Directorate of Extension Education, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The treatment details are given in Table 1. About 500 grams soil sample is taken for laboratory analysis purposes from the experimental area and various soil parameters were analyzed by following standard procedures (Table 2 and 3).

Table 2. Analytical methods followed in soil analysis

Soil characteristics	Method of estimation	Reference
pH	pH (1: 2.5 soil: water)	Jackson (1973)
Electrical conductivity	EC bridge (1: 2.5 soil: water)	Jackson (1973)
Organic carbon	Wet combustion method	Walkley and Black (1934)
Bulk density	Core sampler method	Blake and Hairtge (1986)
Particle density	Pycnometer method	Blake and Hairtge (1986)
Porosity	One minus ratio of bulk density to particle density and multiplied by 100	Blake and Hairtge (1986)
Water holding capacity	International pipette method	Piper (1966)
Available nitrogen	Alkali permanganate method	Subbiah and Asija (1956)
Available phosphorus	Olsen's method	Olsen et al (1954)
Available potassium	Ammonium acetate method	Hanway and Heidel (1952)
DTPA extractable Fe, Mn, Zn, Cu	Atomic absorption spectrophotometer method using DTPA as extractant	Lindsay and Norvell (1978)
Available boron	Hot water soluble	Berger and Troug (1939)

RESULTS AND DISCUSSION

Soil physical parameters: Soil physical parameters were significantly affected by black poly mulch, irrigation and transplanting in broccoli with significantly higher bulk density (1.31 Mg/m^3) in T_{10}, T_{11} and T_{13} (Table 4). The highest particle density (2.63 Mg/m^3) was in T_9 and the lowest particle density (2.43 Mg/m^3) in T_6. The porosity was significantly higher (53.06 %) in T_2. The lowest porosity of 47.91 % was in T_9. Among the water-holding capacity of the soil, the maximum WHC (76%) was in T_6 while the minimum water-holding capacity (58%) in soil in T_{12} and T_{13}, respectively. Black poly mulch significantly affected the physical properties of soil, as it increased the porosity and water-holding capacity of soil and decreased bulk and particle density. The decrease in bulk and particle density might be due to soil loosening brought on by the decomposition of mulches and producing topsoil. However, there is an increment in porosity and water-holding capacity. This might be due to the increased porosity and decreased compaction (due to decreased soil bulk density) in mulched plots that may enhanced aeration and microbial activities in the soil and increased root penetration. Mulching can prevent erosion, inhibit weed growth, and contribute organic matter to the soil (Bot and Benites 2005). Numerous types of organic mulches are frequently used in landscaping to suppress weeds and improve plant health (Tiquia 2002).

Soil Chemical Parameters

pH, electrical conductivity and organic carbon: The significantly higher pH (7.60) was in control and T_{13} followed by T_5 (7.50). The lowest pH (6.80) was in T_3. The electrical conductivity was significantly higher value of 0.82 μs/cm was under T_{13} followed by 0.80 μs/cm in T_{12}. The minimum EC (0.55 μs/cm) was in T_8. Among the organic carbon content of the soil, the maximum organic carbon (2.83%) was in T_7 followed by 2.57% in T_{11}. The lowest organic carbon content of 1.69% in soil was under T_9 and T_1 (Table 5). Among soil chemical parameters, the addition of organic matter during mulch breakdown, which releases organic acids and dissolves them from their soluble state, maybe the cause of the lowered soil pH in mulched treatments. Karp et al (2006) also reported the lowest values of soil pH in mulch treatments. The electrical conductivity of soil was also reduced in treatments with mulch and the reason for the decrease in soil EC may be due to mulches, which decrease soil water evaporation and, in turn, cause less salt to build up in the soil. It may also be because salts that are water-soluble are absorbed by the mulch layer, which lowers the EC of water when it reaches the soil layer. Mulching reduces salt build-up and evapotranspiration (Zhang et al 2008). The lower soil EC could be the result of less salt building up in the topsoil layer. The higher value of organic carbon in treatments with mulch is due to mulching with crop residues increasing nutrient availability and regulating soil temperature The maximum organic carbon recorded in treatment T_7 also encourages beneficial soil microbial activities, worms, soil organic matter, and carbon storage. It also inhibits weed growth and improves product quality, which in turn increases crop health and yield (Lal 2004). It might also be because organic mulches, as they decompose, add carbonaceous material to the soil. Because it might directly affect soil bulk density, the increased soil organic carbon is particularly crucial for crop development.

Available primary macronutrients: The significantly higher soil available nitrogen (361.50 kg/ha) was in T_9 followed by T_{10} and lowest in T_3 (Table 5). Among available phosphorus and available potassium content in the soil, the effect of different treatments was non-significant. The available phosphorus varied from 40.86 to 42.97 kg/ha and available potassium varied from 230.29 to 234.31 kg/ha. The findings presented here are closely consistent with Scharenbroch and Lloyd (2004). The higher soil available nitrogen was recorded in non-mulched treatments and the lowest soil available nitrogen was noted under treatment with mulch. The temporary reduction of soil N availability could result from mulch application. Similar results were also recorded by Rhoades (2012). The effect of black poly mulch, irrigation and transplanting dates on available phosphorus and potassium was remained non-significant. Taufiq et al (2017) also reported that the effects of mulching on some of the soil parameters including available potassium were insignificant.

Table 3. Soil properties before sowing

Soil parameters	Initial values
Soil pH	7.51
Electrical conductivity (μs/cm)	0.70
Organic carbon (%)	1.76
Bulk density (Mg/m^3)	1.32
Particle density (Mg/m^3)	2.62
Porosity (%)	49.65
Water holding capacity (%)	51
Available nitrogen (kg/ha)	348.95
Available phosphorus (kg/ha)	42.14
Available potassium (kg/ha)	232.18
DTPA extractable Cu (mg/kg)	1.57
DTPA extractable Zn (mg/kg)	4.95
DTPA extractable Mn (mg/kg)	15.40
DTPA extractable Fe (mg/kg)	38.02
Available boron (mg/kg)	0.78

DTPA extractable micronutrients: The DTPA extractable micronutrient content in soil varied significantly by the different treatments with maximum DTPA Cu, Zn and Mn (2.18, 9.25 and 20.56 mg/kg, respectively) under T_6. The lowest values of DTPA Cu and Zn (1.75 and 5.18 mg/kg) in T_1. However, the minimum value of DTPA Mn (16.28 mg/kg) was in T_{12}. DTPA extractable Fe, the was maximum (44.12 mg/kg) in T_3 and the minimum (38.46 mg/kg) T_1 (Table 5). The increase in micronutrient content in treatments with mulch is due to the increase in the availability of nutrients in the soil may be related to effective weed management, increased organic carbon contents, and better soil moisture and temperature. The DTPA extractable Cu, Zn and Mn percent increase was maximum under T_6 (38.85, 86.87 and 33.51%). The highest percent increase of 16.04 % DTPA in extractable Fe under T_3. Prasad and Chakravorty (2017) also observed

Table 4. Impact of black poly mulch, irrigation, and transplanting dates on soil physical parameters on broccoli

Treatments	Bulk density (Mg/m^3)	Particle density (Mg/m^3)	Porosity (%)	Water holding capacity (%)
T_1	1.29	2.62	49.43	59
T_2	1.28	2.49	53.06	71
T_3	1.26	2.52	50.00	69
T_4	1.28	2.57	49.61	67
T_5	1.28	2.61	48.47	63
T_6	1.26	2.43	51.64	76
T_7	1.26	2.48	50.40	73
T_8	1.28	2.61	48.47	69
T_9	1.27	2.63	47.91	65
T_{10}	1.31	2.47	53.06	62
T_{11}	1.31	2.57	50.78	59
T_{12}	1.30	2.60	50.38	58
T_{13}	1.31	2.62	50.19	58
Mean	1.28	2.56	50.17	65.31
CD (p=0.05)	0.02	0.05	1.14	2.04

Table 5. Impact of black poly mulch, irrigation, and transplanting dates on soil chemical parameters in broccoli

Treatments	pH	EC (μs/cm)	Organic carbon (%)	Available			DTPA Extractable				Available B (mg/kg)
				N (kg/ha)	P (kg/kg)	K (kg/ha)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Fe (mg/kg)	
T_1	7.60	0.71	1.69	342.16	41.93	230.29	1.75	5.18	17.22	38.46	0.20
T_2	7.00	0.60	2.08	334.24	40.95	232.32	2.04	8.17	20.25	41.05	0.59
T_3	6.80	0.63	2.31	329.41	41.98	231.34	2.05	8.43	18.29	44.12	0.60
T_4	7.30	0.62	1.71	349.87	42.92	232.31	1.80	6.06	16.98	41.49	0.56
T_5	7.50	0.71	1.84	336.75	42.97	233.36	1.87	5.93	16.35	41.89	0.51
T_6	6.90	0.62	2.62	356.19	41.91	234.31	2.18	9.25	20.56	41.61	0.61
T_7	7.00	0.69	2.83	352.48	40.89	231.33	2.15	8.86	19.14	42.08	0.61
T_8	7.20	0.55	1.69	358.89	42.81	232.37	1.84	6.57	17.56	39.85	0.50
T_9	7.30	0.79	1.82	361.50	40.86	231.32	1.80	5.47	16.75	40.60	0.52
T_{10}	7.10	0.69	2.34	360.58	42.84	233.35	1.94	7.28	18.77	42.37	0.55
T_{11}	7.20	0.69	2.57	358.26	41.90	231.38	2.07	8.67	18.37	39.87	0.55
T_{12}	7.40	0.80	1.98	355.78	42.93	233.36	1.91	6.32	16.28	39.34	0.52
T_{13}	7.60	0.82	1.82	340.31	42.93	231.40	1.84	5.70	16.97	39.31	0.51
Mean	7.22	0.69	2.10	348.96	42.14	232.19	1.94	7.07	17.96	40.93	0.53
CD (p=0.05)	0.36	0.03	0.10	17.43	NS	NS	0.10	0.36	0.90	2.03	0.03

that the beneficial interaction between mulches and micronutrients improved soil moisture conservation, which is followed by improved uptake and assimilation of applied nutrients. Sinkeviciene et al (2009) concluded that mulches have a good impact on boosting the number of soil nutrients that are available to plants.

Available boron: The maximum available boron content in soil was under T_6 and T_7 (0.61 mg/kg) followed by T_3 (0.60 mg/kg). whereas, the minimum available boron content (0.20 mg/kg) was in T_1 (Table 5). Mulching led to an increase in available boron content. The available boron content of mulched treatments is comparatively higher than unmulched treatments and control. Similar results were also recorded by Manorama et al (2021) in mulching on oil palm (*Elaeis guineensis* Jacq.).

CONCLUSIONS

Mulches were superior to without mulched treatments in terms of the organic carbon content of the soil. The loosening of soil caused by mulching, which produces topsoil, maybe the cause of the decrease in bulk density and particle density. Bulk density may have increased under the unmulched treatment as a result of surface soil compaction, which had a negative impact on crop development. In dry, semi-arid, subhumid, and temperate regions, intensifying mulching practices leads to an improvement in the physical environment of the soil and enhance plant growth indices. The study concluded that mulches are the most effective way to provide the ideal soil environment for broccoli growth in Himachal Pradesh's mid-hills. Therefore, farmers will employ this method to save moisture, prevent weeds, greatly improve soil health, and increase crop yield. Additionally, this will significantly contribute to attaining sustainable global food security.

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