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Soil and Plant Nutrient Status as Modified by Different Types of Mulching in Cauliflower

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Authors' contributions

This work was carried out in collaboration between all authors. Authors VK and JCS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MK and SKS managed the analyses of the study. Author VK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Mulching is a surface management practice that improves soil environment. A field experiment was conducted on sandy loam soil in mid hills of Himachal Pradesh, India to evaluate the effect of different types of mulch on plant available nutrients and total nutrient contents in cauliflower crop. In two years (2010 & 2011) of experiment four types of mulching material *i.e.*, black plastic mulch (BPM), grass mulch (GM), pine needle mulch (PNM) and no-mulch (NM) were used in RBD with three replications. After completion of two years of experiment the practice of mulching significantly increased the soil organic carbon (SOC) as well as available nutrients (N, P, K, Ca & SO_4^{2-}-S) as compared to NM. However, the higher content of SOC was found in organic mulching (GM & PNM) and the highest content of available nutrients was observed in BPM followed by PNM, GM and NM. Concentration of N, K and Ca nutrient in plant was significantly influenced by mulching treatments while the highest concentration of nutrients was estimated in BPN followed by PNM, GM and NM.

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Thus, practice of mulching could be the better option for improving the nutrient status in soil as well as plant for improvement of quality and quantity of cauliflower crop in mid hill conditions of Himachal Pradesh.

Keywords: Mulching; available nutrients; plant nutrients; cauliflower crop.

1. INTRODUCTION

Cauliflower (*Brassica oleracea* var. botrytis L.), an important vegetable crop of many countries of the World and a member of cole crops, belongs to family Cruciferae. India ranks first in cauliflower production in the world [1]. In Himachal Pradesh, cauliflower is cultivated commercially as off-season crop for remunerative returns. There is more demand in the market even during the dry season. Increased nutritional awareness of people has attracted the farmers to bring large area under cauliflower cultivation. But, owing to poor irrigation facilities which are just limited to 21 per cent of the total cultivated area, the availability of plant nutrients is poor and variable. To overcome these problems the practice of mulching can play an important role in mid hill condition of Himachal Pradesh to meet the partial irrigation water requirement through reduced evaporation and erosion by wind or water, reduced surface run-off and weed growth [2]. Mulching also helps in moderating the soil temperature, increasing soil organic matter and providing plant nutrient source [3] and enhancing the availability of applied and native nutrients. Mulches have the potential to improve soil structure by increasing organic matter, and establish patterns of nutrient cycling as recognized by Fang et al. [4]. However, the effect of mulching on the soil properties may be different for different soils. Also, type and mode of application of mulch materials are important considerations. Many materials have been used as mulch, such as plastic film, crop residue, straw, grass, forest litter, paper etc. [5]. Compared to inorganic mulch, organic mulches provide an attractive and an eco-friendly option [6]. While Barajas-Guzman et al. [7] indicated that polyethylene was the most effective mulch type for early successional species of high growth rate. As mulching materials, organic resources are not only the sources of all essential major and minor nutrients, but also fulfill a number of other functions such as conserving soil moisture, improving soil available nutrient status, ameliorating soil organic matter pool and its quality, and reducing the accumulation of leached nitrate [8]. The application of organic mulch with recommended dose of nutrients provides additional nutrients and humic material through decaying of organic materials (*viz*., organic mulch and crop biomass) and thus provides sustainable source of macro- and micro-nutrients to crops in addition to increasing the nutrient retention capacity of the soil [9]. The inorganic mulch such as plastic sheet of different thickness is largely used nowadays because of limited availability of organic mulches. Mulching prevents direct sunshine, thus checks evaporation from the soil and maintains optimum soil moisture and temperature regimes. Among the mulching materials, the increased usage of polyethylene mulch is due to its benefits when applied in the field, *i.e.,* increases soil temperature, especially in winter, reduces weed problems, enhances moisture conservation, increases crop yields and leads to more efficient use of soil nutrients [10,11]. Generally, researchers using mulching instead of bare soil have recorded higher yield of many crops. Nevertheless, the current study aimed to investigate the effect of different types of mulch on plant available and total plant nutrients in cauliflower crop under mid hill conditions of Himachal Pradesh.

2. MATERIALS AND METHODS

2.1 Description of Study Area

The two years field experiment was initiated during 2009-10 and 2010-2011 at the experimental farm of Department of Soil Science and Water Management, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The soil was gravelly sandy loam in texture. The important physico-chemical properties of the experimental site for 0-15 cm soil depth are presented in Table 1.

2.2 Treatments and Design

The experiment was laid out with 12 treatments replicated thrice in randomized block design during 18th December 2009 to 17th April 2010 and 30th October 2010 to 18th February 2011 (two seasons). The treatments comprised four

Table 1. Physico-chemical properties of experimental soil in 0-15 cm depth before the start of experiment

Properties	Value	Methods
Soil reaction (pH)	6.88	1:2.5 soil : water suspension [12]
Soil organic carbon (SOC)	7.9 g kg^{-1}	Chromic acid titration [13]
Available nitrogen (N)	339.8 kg ha^{-1}	Alkaline permanganate [14]
Available phosphorus (P)	36.2 kg ha^{-1}	Ascorbic acid method [15]
Available potassium (K)	242.6 kg ha^{-1}	1N NH_4OAc (pH 7.0) reagent [16]
Available calcium (Ca)	685.9 kg ha^{-1}	1N NH_4OAc (pH 7.0) reagent [17]
Available magnesium (Mg)	422.8 kg ha^{-1}	1N NH_4OAc (pH 7.0) reagent [17]
Available sulfate sulfur (SO_4^{2-}-S)	51.1 kg ha^{-1}	Turbidimetric method [18]

types of mulches, *viz*., black plastic mulch (BPM), grass mulch (GM), pine needles (*Pinus roxburghii*) mulch (PNM), no-mulch *i.e*. control (NM).

2.3 Field Preparation and Crop Management

The cauliflower seeds of Sweta cultivar were sown in well prepared raised nursery beds about one month before transplanting. Three-weeks-old cauliflower seedlings were transplanted in 3.0 m × 2.5 m plots at the spacing of 60 cm × 45 cm on 18th December 2009 and 30th October 2010. After transplanting (up to two weeks after transplanting), the crop was irrigated daily with pot, thereafter, the crop was given 4 cm life saving irrigations at 15-20 days interval depending upon the prevailing climatic conditions and four irrigations were applied each year. Recommended dose of FYM, N, P_2O_5 and K_2O *i.e.,* 25 t ha^{-1}, 125, 75, 65 kg ha^{-1}, respectively, were applied as per the schedule of the experiment in the form of calcium ammonium nitrate (CAN), single superphosphate (SSP) and muriate of potash (MOP). The whole dose of P and K fertilizers was applied at the time of field preparation. The nitrogen fertilizer was applied in two equal split doses, first dose at the time of transplanting and second one month after transplanting.

2.4 Mulch Application

The UV resistant black plastic sheets were cut in rectangular shape, slightly larger than the dimension of the plots and holes were made by scissor so as to fit the plants in the holes. The mulch sheets were laid in the plots before the transplanting of seedlings. One kg of 100 micron thick black plastic sheet covered about 10 m^2 area. The mulch sheets were placed beneath the soil at the periphery of plots to prevent it from being blown away by wind. The air-dried grass and pine needles mulch materials were spread evenly in the plots to have uniform mulch at the rate of 10 t ha^{-1} just after the establishment of the seedlings (15 days after transplanting). The plastic mulch was removed after the completion of experiment. During second year, beds were prepared and plastic mulch was laid like first year. All the cultural operations were done and doses of nutrients were applied as per the treatment details. The partially decomposed grass mulch and pine needle mulch was allowed to remain in the plot which was later on mixed with soil.

2.5 Soil and Plant Sampling and Analysis

Three representative soil samples from top 15 cm layer were collected after crop harvest from each treatment for the estimation of SOC, available N, P, K, Ca, Mg and SO_4^{2-}-S following standard methods (Table 1). The nutrient content in leaves and curd were determined as per the standard procedures [15].

2.6 Statistical Analysis

Statistical analysis was performed using the SPSS statistical package 13.0. The same letters with table value represent statistically identical values of the examined mulching practices according to Tukey's HSD test determining the least significant difference (LSD) at 5% for testing the significant difference among the treatment means.

3. RESULTS AND DISCUSSION

3.1 Plant Available Nutrients

Availability of soil nutrients depend upon the organic carbon contents in soil, often called as black gold of soil. The two-years data on organic carbon indicates that application of mulching significantly (P=0.05) affect the organic carbon for second year (Table 2). Among the different mulch treatments, grass mulch (GM) enhanced the soil organic carbon (SOC) by 28.0, 25.0 and 6.06% over no-mulch (NM), black plastic mulch (BPM) and pine needle mulch (PNM), respectively while the comparison with initial value of SOC recorded before execution of experiment (2009) the GM increased SOC by 32.9% due to accumulation of carbonaceous material. Organic mulch has the capability to improve the SOC may be due to the fact that organic mulches provide carbonaceous material to the soil upon decomposition. These findings are in accordance with the studies of Shylla and Chauhan [19] and Singh et al. [20] who also observed higher organic carbon contents in soil with organic mulches in fruit crops.

Plant available major nutrients *viz*., nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and sulphur (S) were significantly (P=0.05) influenced with the application of different types of mulch during both the years of study. During first year (2010), the BPM maintained the highest level of available N as compared to NM which was statistically similar to PNM and GM. However, PNM, GM and NM produced similar effect on available N. During second year (2011) application of mulch materials *viz*., BPM, GM and PNM produced statistically similar effect on available N but significantly superior to NM. When compared with the initial value, the increment in availability of N varied from 3.6-4.1% under mulching whereas, NM treatment recorded 2.8% increment after completion of experiment (after two crops). The increase in available nitrogen under plastic mulch is in line with the findings of Raina [21], Gupta and Acharya [22] and Himerlrick et al. [23]. Gao et al. [24] who reported that plastic mulch resulted in significantly increased mineralization of soil organic N, residual nitrate accumulation in the soil profile and reduction in N loss from the soil profile.

Available P was recorded significantly highest in BPM which was statistically at par with GM and PNM however; GM and NM were at par with each other during first year. During second year all mulch treatments were statistically at par with each other but significantly superior to NM. Availability of P was increased by 27.6-35.1% after completion of experiment under mulch treatments over initial value recorded before execution of the experiment. It may be attributed to better hydrothermal regimes, more proliferation of root system and efficient weed control which minimized the P mining. Other possible reason may be that the organic acids produced during the decomposition of organic materials (crop root biomass and organic mulch) complex the metal cations Ca, Al and Fe, thereby helping in solubilization of native P and reduction in P sorption [25].

Available K was significantly improved by 4.3 & 4.0, 3.6 & 3.9 and 2.8 & 2.9% in BPN, PNM and GM during both the years of study, respectively over NM. However, mulch treatments like BPM & PNM, and GM & NM produced statistically similar effect during first year. Likewise, during second year, BPN & PNM, and GM & UM treatments were statistically similar with regard to available K content in soil. When compared to initial value mulch treatments (BPM, PNM and GM) enhanced the available K by 6.3-7.8% in 2010 and 6.7-7.9% in 2011. NM treatment also improved the available K by 3.4 and 3.7% over initial value in respective years. The increase in available K content of soils under mulching may be due to increased elimination of competitive weeds, better hydrothermal regime, higher root biomass which released potassium in soil. Similar explanation has also been given by different workers [22,26,20].

Application of mulch materials *i.e.,* BPM, PNM and GM significantly improved the available Ca as compared to NM but statistically at par with each other during both years of study. However, enhancement in availability of Ca under mulching by 1.6-2.2% and 1.9-2.4% after first and second year, respectively over initial value recorded before start of experiment. NM treatment also increased the available Ca by 1.3% over initial value in both the years. The higher availability of Ca in mulch treatments may be due to breakdown of organic material which releases soluble Ca nutrients and fulvic acid to the soil and in turn increases the soil nutrient availability under mulch [26,20,27].

The available Mg content in soil was not significantly influenced with mulching but numerically the highest was observed in BPM which was followed by PNM, GM and NM during both the years of study.

Availability of sulphate sulfur under mulching *i.e.,* BPM, PNM and GM were also significantly improved by 18.6, 15.7 and 13.3% as compared

Table 2. Effect of different types of mulch on plant available nutrients under cauliflower

Treatments	SOC (g kg^{-1})		N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})		Ca (kg ha^{-1})		Mg (kg ha^{-1})		SO_4^{2-}S (kg ha^{-1})	
	2010	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**
BPM	8.2a	8.4a	352.6a	353.8a	48.3a	48.9a	261.6a	261.8a	700.9a	702.3a	429.3a	430.8a	64.9a	67.7a
GM	9.9a	10.5b	349.2ab	352.0a	45.2ab	46.2a	257.8b	258.8b	697.0a	699.4a	428.6a	429.9a	62.0a	64.3b
PNM	9.7a	9.9b	350.2ab	353.6a	46.4a	47.2a	259.8ab	261.4a	698.5a	701.1a	429.1a	430.2a	63.3a	66.1b
NM	8.2a	8.2a	348.0b	349.4b	40.9b	41.3b	250.8c	251.6b	694.2b	694.8b	427.1a	427.5a	54.7b	56.3c
LSD $_{(0.05)}$	NS	0.50	2.56	1.41	5.13	4.10	2.43	2.55	5.07	4.76	NS	NS	3.12	3.21

BPN: Black plastic mulch; GM: Grass mulch; PNM: Pine needle mulch; NM: No-mulch
Different letters in a column indicate significant difference (at 5% level) between the means according to Tukey's HSD test

Table 3. Effect of different types of mulch on total plant nutrients (leaves + curd) under cauliflower

Treatments	N (%)		P (%)		K (%)		Ca (%)		Mg (%)		S (%)	
	2010	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**
BPM	2.51a	2.72a	0.31a	0.34a	2.10a	2.25a	1.58a	1.86a	0.23a	0.24a	0.23a	0.25a
GM	2.47a	2.67b	0.28a	0.33a	2.07a	2.20b	1.55a	1.82a	0.23a	0.23a	0.21a	0.23a
PNM	2.49a	2.69ab	0.30a	0.32a	2.08a	2.23a	1.56a	1.84a	0.23a	0.24a	0.22a	0.24a
NM	2.41a	2.45c	0.25a	0.26a	2.02a	2.09c	1.52a	1.64b	0.21a	0.21a	0.19a	0.19a
LSD $_{(0.05)}$	NS	0.03	NS	NS	NS	0.02	NS	0.04	NS	NS	NS	NS

BPN: Black plastic mulch; GM: Grass mulch; PNM: Pine needle mulch; NM: No-mulch
Different letters in a column indicate significant difference (at 5% level) between the means according to Tukey's HSD test

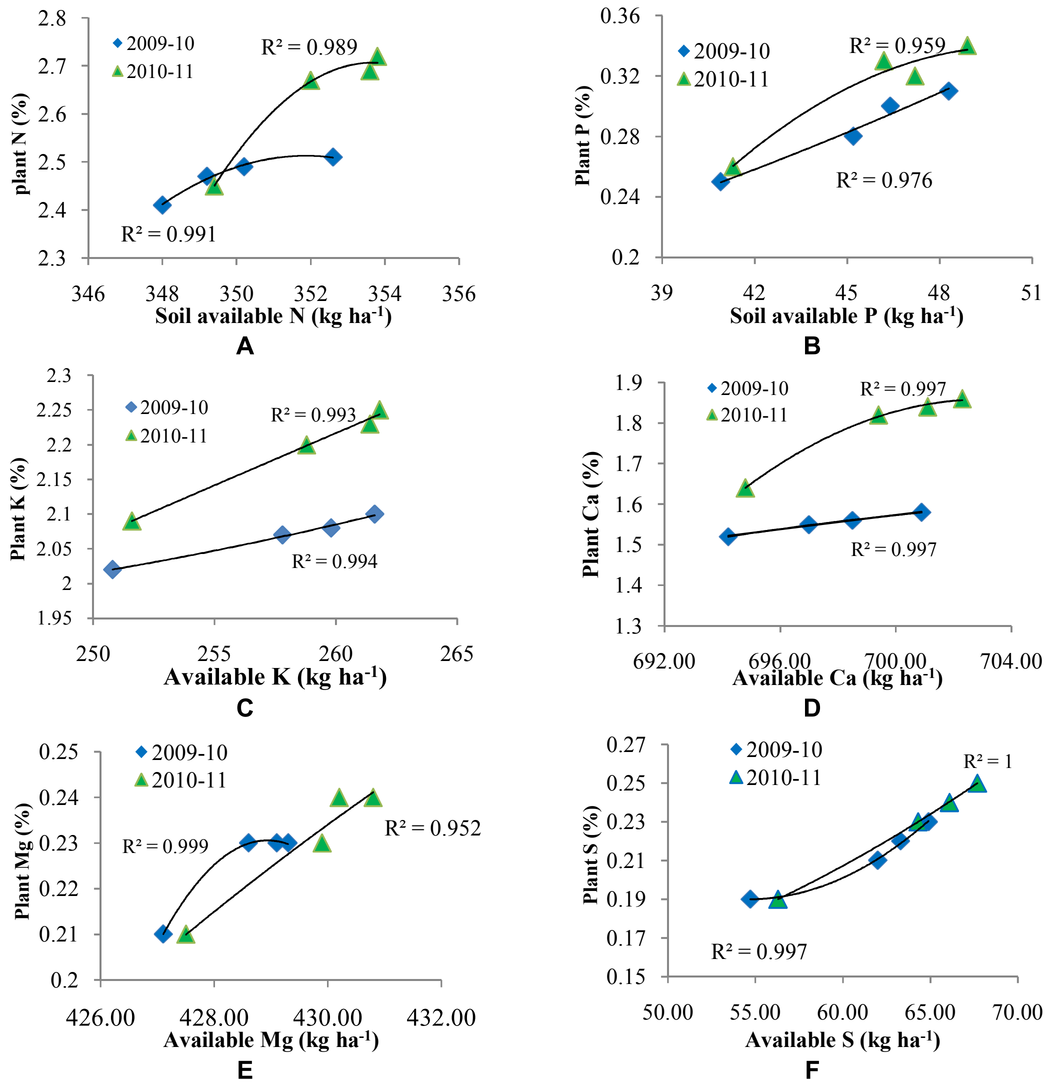

Fig. 1. Polynomial relationships between (A) plant available N and total plant N (B) plant available P and total plant P (C) plant available K and total plant K (D) plant available Ca and total plant Ca (E) plant available Mg and total plant Mg and (F) plant available S and total S in different mulch treatments

to NM but statistically at par with each other during first year. During second year, the BPM maintained the highest (67.7 kg ha^{-1}) level of available SO_4^{2-}-S as compared to rest of the treatments, whereas, PNM and GM were significantly superior to NM but statistically at par with each other. When compared to initial value the mulch treatments in BPM, PNM and GM increased the available SO_4^{2-} -S by 32.5, 29.4 and 25.8%, respectively after completion of second year of experiment. This may be due to the reason that organic residues upon decomposition, under mulching, add organic acids to the soil resulting in low soil pH, which may increase the bioavailability of sulfur [6,26,17].

4. TOTAL PLANT NUTRIENTS

Majority of nutrients in plant were not significantly influenced with the application of mulch during first year of experiment (Table 3). Nevertheless, the highest content of N, P, K, Ca, Mg, and S was recorded in BPM followed by PNM, GM and NM. During second year of experiment, nutrients like N, K and Ca were significantly (P=0.05) influenced with application of mulching (Table 2). Treatment BPM maintained the highest (2.72%) level of N content in plant which was statistically at par with PNM (2.69%) while the GM and PNM produced statistically similar effect on N content in plant. K content in plant was also significantly the highest in BPN (261.8%) which was statistically similar to PNM. Ca content in plant was also significantly affected by mulching as compared to NM but all mulching treatments (BPM, PNM and GM) were statistically at par with each other. The efficient utilization of nutrients under mulch treatments could be expected because of enlarged, more fibrous, and more active surface feeder roots as conditioned by favorable moisture and thermal regimes, thereby resulting in greater uptake of nutrients by plants under mulch. The significant effect of different mulching materials on nutrient content in plants is in conformity with the work of Bhat [26] and Panwar [28].

5. RELATIONSHIP BETWEEN SOIL AND PLANT NUTRIENTS

A positive relationship existed (R^2 = > 0.90) between the plant available nutrients and nutrients content in plant (Fig. 1). All the soil nutrients were highly correlated with plant nutrients. This indicated that greater amount of soil organic matter was added to soil by organic mulch, and also mulching provided better hydrothermal regime which enhanced the availability of nutrients in soil as well as uptake of nutrient by crop.

6. CONCLUSION

The results of this study exhibited that mulching is beneficial for achieving higher availability of plant nutrients in soil as well as total nutrient content in crop in coarse-textured soils under rainfed conditions in mid-hill region of Himachal Pradesh. Application of black plastic mulch (BPM) is as good as grass (GM) and pine needle (PNM) mulches for inducing hydrothermal conditions congenial for higher nutrient availability and better correlation with plant nutrients. The decomposition of GM and PNM, however, supplied soil nutrients and improved soil fertility.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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