Enhancing Sustainability of Broccoli production through Integrations of Mulching and Nitrogen Sources

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Abstract

The current experiment was carried out at the Horticulture research farm of Lovely Professional University, Punjab, during the year 2021-22. Experiment was carried out in FRBD (Factorial Randomized Block Design) replicated thrice. The treatment consisted of six nitrogen doses from different sources as N_0-0% N (control), N_1-100 % N with Urea (260 kg ha^{-1}), N_2 -50% N with Urea (130 kg ha^{-1}) +50% N with Cow dung (10 t ha^{-1}), N_3-50% N with Urea +50% N with FYM (10 t ha^{-1}), N_4-50% N with Urea +50% N with Vermicompost (10 t ha^{-1}) and N_5-50% N with Urea +50% N with Poultry Manure (7 t ha^{-1}) along with three mulching treatments *viz*, M_0-Without mulch (control), M_1- paddy Straw mulch and M_2 - Black Polythene mulch. Among the treatments combination N_5M_2 was found superior for most of the growth and yield parameters under study *viz*. plant height, number of leaf, plant spread, days to head initiation, head weight, head diameter and yield i.e. 38.3cm, 17.33, 1885.60 cm^2, 72 days, 553g, 16.4cm, 13.1 qha^{-1} respectively however, in quality parameters highest total chlorophyll was observed in treatment N_3M_2 i.e. 22.3, while maximum total sugar recorded in N_0M_2, crude fibre was highest in treatment N_1M_2 i.e. 1.75 (%). N_4M_1 was observed significant superior in proline, protein, flavonoids *viz*, 37.9 (%), 0.49 (mg/g) and 36.9 respectively. N_5M_1 showed significantly high in Sulphoraphane 691.2μg/g per dry matter. While minimum Sulphoraphane content (516.8μg/g dry matter) was found in N_2M_2. However minimum days to head initiation (60.1 days) was observed in the treatment combination N_1M_0.

Keywords: Broccoli; Nitrogen; Mulching; Proline; Sulforaphane.

1. Introduction

Broccoli is a important crop in manners of nutrition and pecuniary cultivated throughout world. Broccoli is an important vegetable among the cole crops. It is often known as Hari ghobi (*Brassica oleracea* var. *Italica*) with chromosome no. 2n= 18. Its name 'Broccoli' is derived from a Latin word "Brachium" (Panjwani *et al.,* 2018). Broccoli content vitamins, antioxidants, glucosinolates and anti-carcinogenic compounds which make it popular among people's. Sulforaphane is one the crucial component extracted from broccoli. Sulforaphane is the chemoprotective, anti-inflammatory phytochemical obtained from broccoli (Pocasp *et al.,* 2013). In 2022, the broccoli production was 27.8 million tonnes worldwide with China and India together accounting 69.4% the total production of world. In India, broccoli consider as commercial crop. Broccoli grows under 4.3 Lakh hectares in India as compared to 13.9 lakh hectares in world. About 27.6% area is occupied by Punjab under cultivation of broccoli from total area (Anonymous 2015).

Introducing organic and bio-approaches as alternatives to traditional chemical fertilization have helped raise consumer awareness of food safety and environmental concerns. But as compared to conventional mineral fertilizers, the effectiveness of these fertilizers was somewhat poor. Nitrogen is a key plant nutrient, has a crucial role in growth and developments of crops. Broccoli id a heavy nutrient feeders and will do well with a proper dose of fertilizer. Application of equitable fertilizer shows a finer result which gives plants enough energy to get large full heads of broccoli. Today's call for the farmers is to manage plant nutrition with combined nutrient management entail organic & inorganic fertilizers which can further help in rectifying and maintenance of soil fertility. Integrated nutrient management not only improves and sustains the properties of soil but also prevents the secondary and micronutrient deficiencies (Dhakal *et al.,* 2016).

The word 'mulch' is obtained from "molsch" a German word meaning soft to decay, which refers to the use of leaves and straw by farmers on the field as mulch. In horticulture mulches were used in various manners in arid and semi-arid regions like Punjab for erosion control and water conservation. Mulch is also used for soil temperature modification, soil conservation and weed control. It provides nutrients on decomposition of organic mulch, improvement of soil structure and helps indirectly in increasing of quality and yield of crop (Regar *et al.,* 2018). Soil degradation reduced with by mulching and prevents soil loss by runoff, reduced the weed growth, water evaporation, conserving soil moisture, helps in the improvement of physical, enhance chemical and biological properties of soil.

2. Materials and Method

2.1. Site of experimentation

The experiment was conducted during the year of 2021–22 at agriculture farm of lovely professional University, Punjab, India. The experimental area is located at 31.20^0N 75.3^0E. The climate of experiment site comes under subtropical monsoon with an average rainfall of 613 mm of central plane region of Punjab containing sandy loam soil.

2.2. Experimental details:

The experiment was carried out in FRBD design which was replicated thrice. The treatments consisted of six integrated doses of nitrogen viz., 0% N;N_0 (control), 100 % N (120 kg/ha.) with Urea;N_1, 50% N with Urea +50% N with Cow dung;N_2, 50% N with Urea +50% N with FYM;N_3, 50% N with Urea +50% N with Vermicompost;N_4 and 50% N with Urea +50% N with Poultry Manure; N_5 along with three different mulching treatments as Without mulch;M_0 (Control), Paddy Straw mulch;M_1 and Black Polythene mulch;M_2. The treatments consisted of 18 combinations of nitrogen and mulching. The broccoli variety "Palam Samridhi" was used to assess its potential under combination of nitrogen and mulching material. The seedlings were transplanted at 4-5 leaves stage with a spacing of 60cm $\times$ 30cm.

Table 1: Treatment details

S.No.	Treatments	Treatment combination
1	N_0M_0	0% N
2	N_0M_1	0% N + Paddy Straw mulch
3	N_0M_2	0% N + Black Polythene mulch
4	N_1M_0	100 % N with Urea + Without Mulch
5	N_1M_1	100 % N with Urea + Paddy Straw mulch
6	N_1M_2	100 % N with Urea + Black Polythene mulch
7	N_2M_0	50% N with Urea & 50% N with Cow Dung + Without Mulch
8	N_2M_1	50% N with Urea & 50% N with Cow Dung + Paddy Straw mulch
9	N_2M_2	50% N with Urea & 50% N with Cow Dung + Black Polythene mulch
10	N_3M_0	50% N with Urea & 50% N with FYM + Without Mulch
11	N_3M_1	50% N with Urea & 50% N with FYM + Paddy Straw mulch
12	N_3M_2	50% N with Urea & 50% N with FYM + Black Polythene mulch
13	N_4M_0	50% N with Urea & 50% N with Vermicompost + Without Mulch
14	N_4M_1	50% N with Urea & 50% N with Vermicompost + Paddy Straw mulch
15	N_4M_2	50% N with Urea & 50% N with Vermicompost + Black Polythene mulch
16	N_5M_0	50% N with Urea & 50% N with Poultry Manure + Without Mulch
17	N_5M_1	50% N with Urea & 50% N with Poultry Manure + Paddy Straw mulch
18	N_5M_2	50% N with Urea & 50% N with Poultry Manure + Black Polythene mulch

N= Nitrogen doses, **M**= Mulching material.

2.3. Growth and yield characters:

For recording observations, five competitive plants were randomly marked from each plot,

growth parameter viz., plant height (cm), plant spread $(cm)^2$, number of leaf plant^{-1},days to head initiation, head weight (g), head diameter (cm) and yield/ha (q/ha) at a regular interval at 15,30 and 45 days after transplanting and at harvest. The yield and quality parameter were observed at harvest. Biochemical analysis viz., Total chlorophyll (mg/g) Total sugar (%), Crude fibre (%), Proline (%), Flavonoids (%) and Sulphoraphane (µg/g dry matter) were performed in the research laboratory of lovely professional university. All the data recorded during the research trial was subjected to statistical analysis.

2.4. Biochemical characters:

The total protein in a plant sample is calculated using the Bradford protein assay (Bradford 2011). Protocol for Proline Assays For proline estimation, 10g of leaf extract is mixed with 100°C of hot and cold water for 10, 30, and 60 minutes. Whatman No. 1 was used to filter the extractions. Proline activity and antioxidants were tested in the filtrates using the DPPH free radical scavenging assay. To estimate chlorophyll A 0.5-gram fresh plant sample was homogenized with 20 ml of 80% cold acetone in dark. $MgCO_3$ powder in minimal amounts is added. Whatman no. 1 paper is used to filter the extract. By adding 80% acetone to a conical flask lined with black carbon paper, the final volume was made up to 100 ml. At 645 nm and 663 nm, the absorbance was measured using 80% acid as a blank medium.

2.4.1. Sulphoraphane

Broccoli plants were collected from different treatments. Standard was purchased from (St. Louis, MO) Sigma Chemical Co. Apparatus. Two certified HPLC systems were used. Acetonitrile was HPLC grade, and anhydrous sodium sulfate and methylene chloride were reagent grade. For sample preparation, 400 g of broccoli kept in boiling water for 6 minutes. After boiling, drain the water and kept undisturbed for 30 minutes. After that, the solid parts of the broccoli were removed, and the aliquot was directly lyophilized—prepared extract analyzed by HPLC.
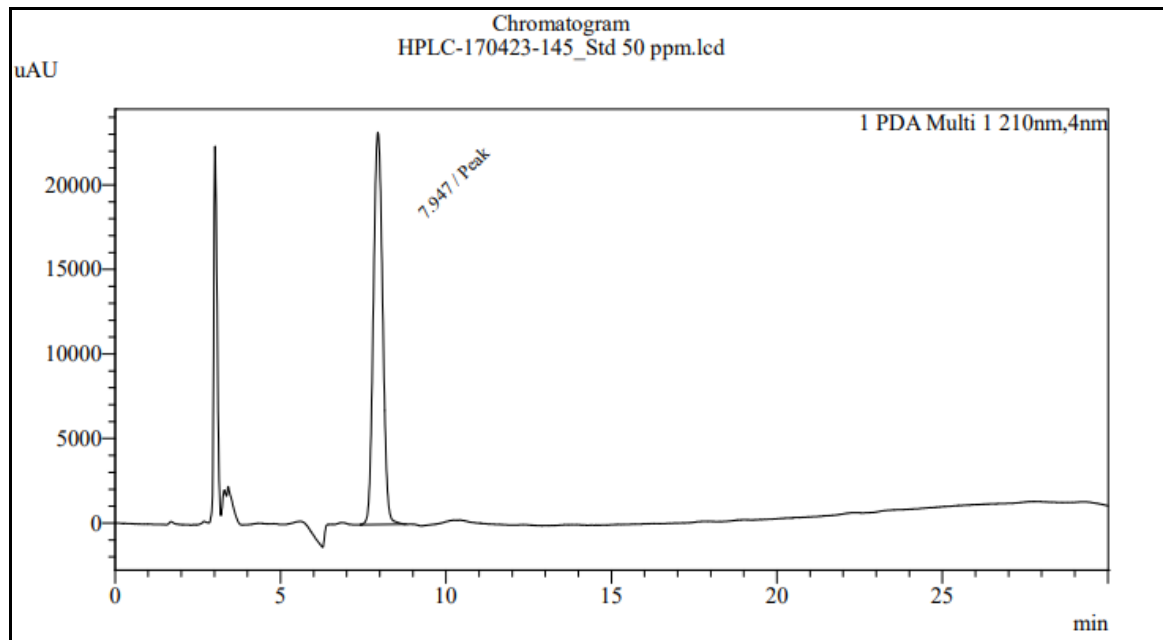
Fig.2. Chromatograms of Sulphoraphane (HPLC scouring profile of broccoli sample)

2.5. Soil analysis

A complex sample of soil from 0-30 cm soil depth were collected from the experimental field prior to commencement of the trial and at the end of trial for estimation of availability of N,P and K in soil.

2.6. Statistics analysis

The growth parameter analysis was done by using OPSTAT version software. The two ways ANOVA for factorial randomized block design and standard error of means (SEm±) were used in the statistical analysis of the data gathered over the study of research where the F value was determined to be significant were critical differences (CD) at the 5% level of probability assessed.

3. Result and Discussion

The data from Table 1 unveil that maximum plant height found in treatment N_5M_2 (38.3 cm) which was significantly superior over treatment N_1M_2 (37.6 cm) and N_4M_2 (36.6 cm). The minimum plant height was noted under treatment N_0M_0 (24.0 cm). The combined effect of nitrogen with urea and poultry manure tends to aid in primary growth of broccoli result in getting maximum plant height. The black mulch conserve the more amount of moisture within root area of plant assist easy utilization of nutrients by plants. In case of days to head initiation, the minimum days to head initiation was noticed in treatment N_1M_0 (62.1 days). The Maximum days to head initiation was recorded under treatment N_0M_0 (70.7 days). The application of nitrogen with urea initiated the process of head initiation more quickly as

1574

compared to other treatments resulting in minimum days taken for head initiation. The Number of leaves was significantly influenced by the different treatment combination. The highest number of leaves was found in N_5M_2 (17.33 no. plant^{-1}) followed by treatment N_4M_2 (15.56 no. plant^{-1}) while the minimum number of leaves was observed in treatment N_0M_0 (9.33 no. plant^{-1}). The widest plant spread was observed in N_5M_2 (1885.60cm^2) followed by treatment N_1M_2 (1862.73cm^2) the minimum plant canopy was found in N_0M_0 (1422.87cm^2) However in treatments receiving the nutrition with manures takes more days for head initiation. The similar findings were proposed by (Fahey *et al.,* 2015; Chartoumpekis *et al.,* 2019; Das *et al.,*2019; Mahn *et al.,* 2021; Kumar *et al.,* 2023).

The economical part of broccoli is head. The head weight directly regulates yield. In present study, maximum head weight, head diameter and yield/ha were recorded in the treatment N_5M_2 i.e., 553.2 g, 16.4 cm and 13.1 qha^{-1} respectively followed by N_1M_2 i.e., 510.9 g, 15.8cm and 12.8 qha^{-1} respectively. The minimum head weight, head diameter and yield/ha were found in the treatment N_0M_0 i.e. 310.5 g, 10.7cm respectively where as minimum yield was found in N_0M_0 (5.34 qha^{-1}). Yield was the important growth parameter, in context of present investigation. The increase in head weight and head diameter mainly aided by the proper amount of nutrients provided through treatments. The combinations of nitrogen with urea and poultry manure along with black polythene mulch enhanced the head weight and head diameter. The total nitrogen regulated by urea also impacts the head weight in broccoli. Rising traits such as head weight and diameter reflect in simultaneous uplifting the yield of broccoli. The present result was supported by findings of (Natella *et al.,* 2016; Jaime *et al.,* 2016; Mohanta *et al.,* 2018; Meena *et al.,* 2017).

Crude fiber present in broccoli at higher amounts was recorded under treatment N_1M_2 (1.75%) significantly followed by treatment N_2M_2 (1.65%) at par with N_4M_1 (1.65%). The lowest value for crude fiber was recorded in treatment N_0M_2 (0.81%). The crude fiber in broccoli was increased by absorption of direct amount of nitrogen. The nitrogen with urea along with cow dung enhanced the soil nutrient level which gets boosted by application of black mulch and paddy straw mulch aid to improve crude fiber in broccoli. The chlorophyll content presented in Table 1, this study divulged that the maximum amount of total chlorophyll was recorded in treatment N_3M_2 (22.3 mg/g) significantly followed by treatment N_1M_2 (21.3mg/g). The minimum quantum of total chlorophyll was recorded for treatment N_5M_0 (9.9mg/g). The total chlorophyll was influenced by the adequate amount of nitrogen with urea along with well decomposed FYM way up chlorophyll level in broccoli. The use of black polythene mulch along with FYM and urea aid the final result of total chlorophyll. The

1575

similar findings were put forward in support by (Doklega *et al.,* 2017; Kumar *et al.,* 2017; Ujjwal *et al.,* 2020). Data depicted in Table 1 divulged that, maximum amount of proline and protein content in broccoli was recorded in treatment N_4M_1 (37.9%), (0.49mg/l) which was significantly followed by treatment N_5M_2 (36.1%) and N_5M_2 (0.44 mg/l) respectively. The minimum amount of proline and protein was recorded under treatment N_4M_2 (26.7%), N_2M_2 (0.24 mg/l) respectively. Protein is one of the crucial components of broccoli. In respect to present investigation, Flavonoids present in broccoli was estimated and depicted in (Table 1). The maximum amount of flavonoids was recorded in treatment N_4M_1 (36.9%) which was significantly followed by treatment N_2M_1 (36.7%). The minimum amount of flavonoids was recorded in treatment N_0M_2 (23.8%). The Sulphoraphane present in broccoli recorded highest concentration in treatment N_5M_1 (691.2μg/g dry matter) which was significantly followed by treatment N_2M_1 (674.1 μg/g dry matter) (Table 1). The minimum amount of Sulphoraphane was recorded for the treatment N_2M_2 (516.8 μg/g dry matter). (Scahill *et al.,* 2015; Fahey *et al.,* 2017; Jiang *et al.,* 2018). The half amount of nitrogen through direct dose by urea along with organic manure enhance the quality attributes of broccoli such as proline, protein, flavonoids and sulforaphane. The organic manure aided the availability of nutrients responsible for boosting the level of different quality traits. In present investigation, the variation in nitrogen dose apply along with various organic manure such as FYM, cow dung, vermicompost and poultry manure in combination with paddy straw mulch and black polythene mulch reflect variated results. The experimental findings were supported by (Sivapalan *et al.,* 2018; Sudini *et al.,* 2016; Fahey *et al.,* 2019).

4. Conclusion

As per the above mentioned investigation, we can conclude that the incorporation of N_5M_2 (50% N with Urea +50% N with Poultry Manure + Black Polythene mulch) mainly influenced the growth prospective traits in broccoli whereas N_3M_2 (50% N with Urea +50% N with FYM + Black Polythene mulch) contributed towards increase in chlorophyll amount. The precious quality attributes such as proline, protein, flavonoids and sulphoraphane influences by presence of N_5M_2(50% N with Urea +50% N with Poultry Manure + Black Polythene mulch) along with N_5M_1 (50% N with Urea +50% N with Poultry Manure + Paddy Straw mulch) can be recommended for profitable and quality broccoli production.

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1577

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Table 1: **Assessment of growth, yield and biochemical characters of broccoli under combined approach of integrated nitrogen Management and mulching.**

Treatments	Growth characters				Yield characters			Biochemical characters						
	Plant Height (cm)	Number of leaf (number)	Plant spread (cm^2)	Days to Head Initiation (Day's)	Head weight (g)	Head Diameter (cm)	Yield/Ha (Qha^{-1})	Total Chlorophyll (mg/g)	Total sugar (%)	Crude Fibre (%)	Proline (%)	Protein (mg/g)	Flavonoids (%)	Sulphoraphane (µg/g dry matter)
N_0M_0	24.0	9.33	1422.87	70.7	310.5	10.7	5.3	11.5	0.249	0.95	28.1	0.31	28.1	538.1
N_0M_1	25.0	9.73	1451.73	68.7	312.8	11.1	6.8	15.8	0.067	0.85	29.8	0.30	27.6	542.9
N_0M_2	24.7	10.8	1467.23	64.8	329.4	10.9	6.3	17.0	0.390	0.81	29.5	0.32	23.8	564.1
N_1M_0	34.0	12.26	1761.93	62.1	354.8	12.1	9.6	10.2	0.177	1.20	29.2	0.30	27.1	518.3
N_1M_1	30.9	12.23	1707.97	63.9	485.3	13.6	10.2	13.0	0.016	1.05	33.6	0.36	30.1	632.7
N_1M_2	37.6	17.23	1862.73	65.7	510.9	15.8	12.8	21.3	0.014	1.75	33.7	0.39	32.4	654.2
N_2M_0	31.3	12.13	1615.77	67.7	364.8	12.5	9.5	15.5	0.343	1.15	30.4	0.29	28.3	594.2
N_2M_1	32.7	13.60	1681.90	63.2	360.7	11.7	9.6	11.4	0.026	0.85	34.7	0.41	36.7	674.1
N_2M_2	32.0	14.10	1692.90	67.1	501.3	14.2	10.6	20.1	0.223	1.65	27.3	0.24	25.2	516.8
N_3M_0	28.9	13.40	1513.87	69.5	384.7	12.2	9.8	13.4	0.012	1.15	30.7	0.28	28.7	520.7
N_3M_1	32.1	12.46	1562.23	69.2	409.1	13.3	9.9	16.2	0.009	1.18	32.1	0.38	30.7	551.3
N_3M_2	32.3	14.90	1802.57	67.2	477.3	13.8	10.5	22.3	0.016	1.05	34.4	0.34	29.8	643.9
N_4M_0	30.6	14.13	1672.97	68.1	467.9	12.8	10.6	14.7	0.105	1.35	32.4	0.27	24.6	526.1
N_4M_1	29.7	13.93	1666.87	67.0	491.7	13.9	10.6	13.3	0.071	1.65	37.9	0.49	36.9	623.8
N_4M_2	36.6	15.56	1842.67	67.2	453.1	13.0	10.2	10.3	0.066	1.40	26.7	0.26	33.6	531.2
N_5M_0	32.4	15.40	1802.33	65.7	429.7	12.4	10.1	9.9	0.017	1.25	31.5	0.27	29.0	619.4
N_5M_1	33.0	14.26	1646.50	68.7	461.1	12.7	10.4	12.7	0.012	0.95	35.8	0.46	35.4	691.2
N_5M_2	38.3	72.2	1885.60	72.2	553.2	16.4	13.1	11.7	0.101	1.40	36.1	0.44	35.1	681.2
SE(m)±	0.35	0.23	0.28	0.32	0.29	0.12	1.52	0.13	0.05	0.08	0.37	0.04	0.43	0.39
CD @ 5%	1.00	0.67	0.82	0.93	1.28	0.35	2.13	0.36	0.15	0.24	1.09	0.73	1.26	1.62

N_0M_0 = 0% N, N_0M_1 = 0% N +Paddy Straw mulch, N_0M_2 = 0% N + Black Polythene mulch, N_1M_0 = 100 % N with Urea + Without Mulch, N_1M_1 = 100 % N with Urea + Paddy Straw mulch, N_1M_2 =100 % N with Urea + Black Polythene mulch, N_2M_0 = 50% N with Urea +50% N with Cow Dung + Without Mulch, N_2M_1 = 50% N with Urea +50% N with Cow Dung + Paddy Straw mulch, N_2M_2 = N with Urea +50% N with Cow Dung + Black Polythene mulch, N_3M_0 = 50% N with Urea +50% N with FYM + Without Mulch, N_3M_1 = 50% N with Urea +50% N with FYM + Paddy Straw mulch, N_3M_2 = 50% N with Urea +50% N with FYM + Black Polythene mulch, N_4M_0 = 50% N with Urea +50% N with Vermi compost + Without Mulch, N_4M_1 = 50% N with Urea +50% N with Vermi compost + Paddy Straw mulch, N_4M_2 = 50% N with Urea +50% N with Vermi compost + Black Polythene mulch, N_5M_0 = 50% N with Urea +50% N with Poultry Manure + Without Mulch, N_5M_1 = 50% N with Urea +50% N with Poultry Manure + Paddy Straw mulch, N_5M_2 = 50% N with Urea +50% N with Poultry Manure + Black Polythene mulch.