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Effect of integrated nutrient management on growth and quality traits of lettuce (*Lactuca sativa*)

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ABSTRACT

A field experiment was conducted at the research farm of Assam Agricultural University, Jorhat, Assam during winter (*rabi)* seasons of 2019–20 and 2020–21 to study the effect of integrated nutrient management on growth and quality of lettuce (*Lactuca sativa* L.). The experiment was laid out in a randomized block design (RBD) with eight treatments and three replications. The treatment combinations were T_1, Control; T_2, 40:20:40 NPK kg/ha; T_3, 40:20:40 NPK kg/ha + FYM 2 tonnes/ha; T_4, 40:20:40 NPK kg/ha + FYM 2 tonnes/ha + PSB; T_5, FYM 3 tonnes/ha + PSB; T_6, 40:20:40 NPK kg/ha +VC 1 tonnes/ha; T_7, 40:20:40 NPK kg/ha + VC 1 tonnes/ha + PSB and; T_8, VC 2 tonnes/ha + PSB. Observations on the growth parameters were taken at 30 DAP, 45 DAP and at harvest. Among the treatments, T_7 recorded the highest yield (27.5 tonnes/ha), net income (192703.00) and other quality parameters. However, the benefit-cost ratio was found maximum (2.6) in the treatment T_4 due to lesser cost of FYM as compared to vermicompost used in the treatment T_7. Therefore, the combined use of NPK, FYM and PSB (T_4) may be recommended for economic as well as environment friendly production of lettuce.

Keywords: Economics, FYM, Lettuce, Quality, Vermicompost, Yield

Lettuce (*Lactuca sativa* L.) is an important salad crop mainly grown in the temperate and subtropical region and belongs to family Asteraceae. The most suitable day temperature for cultivation of lettuce is 18–25°C and the night temperature is 10–15°C. It is well known as anodyne, sedative, diuretic and expectorant (Kalloo 1986). Lettuce grows well in soil rich with nutrients. It is a highly nutritive vegetable and it contains carbohydrate, protein, fat and minerals (calcium, phosphorus and iron). Consumption of lettuce reduces blood cholesterol, obesity, diabetes and improves blood structure. Lettuce being a succulent vegetable, fertilizer should be applied at appropriate dose and time with sufficient irrigation. Increased use of inorganic nitrogen in lettuce has significantly increased the nitrate content of the leaves as well as the environmental pollution. With the application of biofertilizers, the nitrate content of the leaves is reduced remarkably. So, for better performance of lettuce, chemical fertilizers, organic manures and biofertilizers are being used together (Mantur *et al.* 2018). From various experiments, it has been observed that inorganic fertilizers enhanced the crop yield but their continuous application polluted the air, water, deteriorated the physical health of soil, released greenhouse gases and thereby caused hazards to human health and to the environment. So, an effective nutrient management approach such as integrated nutrient management (INM) must be adopted. INM is a well-accepted approach for the sustainable management of soil productivity and increased crop production. The main aim of the INM is to sustain productivity with minimum deleterious effects on soil health and the environment. This enhances the nutrient use efficiency, maintains soil health, enhances yield and reduces the cost of cultivation (Paudel *et al.* 2004). Hence the use of integrated nutrient management becomes indispensable for maximizing vegetable production, productivity, sustaining soil health and quality. There is an insistent need to take up an integrated nutrient management system for providing efficient and balanced use of various plant nutrients therefore, the present study was carried out with an objective to study the effect on INM on lettuce yield and quality.

MATERIALS AND METHODS

The present study was carried out at the research farm of Assam Agricultural University, Jorhat, Assam during winter (*rabi)* seasons of 2019–2020 and 2020–21. The soil used for cultivation was sandy loam. The variety used was Grand Rapid (leaf type) which is an early maturing variety. The experiment was conducted in randomized

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block design with eight treatments and three replications. The treatments consisted of nitrogen (N), phosphorus (P), potash (K), farmyard manure (FYM), vermicompost (VC) and phosphate solubilizing bacteria (PSB) in different combinations. The treatment combinations were T_1, Control; T_2, 40:20:40 NPK kg/ha; T_3, 40:20:40 NPK kg/ha + FYM 2 tonnes/ha; T_4, 40:20:40 NPK kg/ha + FYM 2 tonnes/ha + PSB; T_5, FYM 3 tonnes/ha + PSB; T_6, 40:20:40 NPK kg/ha +VC 1 tonnes/ha; T_7, 40:20:40 NPK kg/ha + VC 1 tonnes/ha + PSB and; T_8, VC 2 tonnes/ha + PSB. The size of the plot was 1.5 m^2. After the preparation of the land, fertilizers, i.e. NPK @40:20:40 kg/ha as urea, single super phosphate (SSP) and muriate of potash (MOP) were applied to the various plots according to the treatments one week prior to planting. Similarly, vermicompost and farm yard manure were also applied to the plots as per the treatment schedule. For the application of biofertilizers, the seedlings were inoculated with phosphate solubilizing bacteria. The fertilizers and organic manures were carefully incorporated into the soil. The seedlings were planted at a spacing of 30 cm row to row and 25 cm plant to plant. Five healthy plants in each plot from each replication were tagged for taking the observations on morphological characters. Observations were recorded on plant height, number of leaves per plant, leaf length, leaf breadth, leaf canopy spread, leaf area, leaf area index, fresh and dry weight of the leaves, days to marketable maturity, yield and harvest index. The quality parameters, viz. ascorbic acid, reducing and non-reducing sugar, chlorophyll, calcium, iron, nitrogen and crude protein content were analyzed during 2020–21 by using standard methods. For determination of nutritional traits such as ascorbic acid content, chlorophyll content, reducing sugar and non-reducing sugar content fresh sample is required. The leaves were taken from each of the eight treatments from three replications and these were mixed treatment wise and two replicates from the mixture were prepared for each of the eight treatments for estimation of quality parameters. For determination of calcium, iron, nitrogen and crude protein dried samples are required, so the leaves were oven dried at 60°C for 72 h until the leaves were completely dried up (Rangana 1986). The dried samples from each treatment were ground into powder form and stored in air tight condition in a polypropylene bag. Each value of a treatment in each laboratory replication was used for statistical analysis and interpretation was done by using the completely randomized design (CRD). The morphological data obtained during the two years of experiments were subjected to statistical analysis as per the procedure given by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Effect of integrated nutrient management on growth and yield: Integrated nutrient management helps to restore and maintain soil fertility and crop productivity. It improves the physical, chemical and biological environment of the soil. It also enhances the moisture holding capacity and infiltration rate of the soil. The mean performance of the Grand Rapid variety of lettuce by using eight different treatments across 2019–2020 and 2020–2021 showed significant variations in respect of various growth characters and yield among the treatments.

The pooled data (Table1) for two consecutive years showed that the treatment T_7 recorded the maximum plant height 14.25 cm, 19.17 cm and 26.92 cm at all the three growth stages, viz. 30 DAP, 45 DAP and at harvest, respectively. The highest number of leaves per plant with values 10.0, 17.2 and 29.2 at 30 DAP, 45 DAP and at harvest respectively, were also exhibited by the treatment T_7. The lowest mean values for plant height and number of leaves per plant was observed in the treatment T_1 (control). The highest values in these treatments might be due to the integrated application of inorganic and organic fertilizers which provided for high photosynthetic activity and vigorous vegetative growth of the plant. The applications

Table 1 Effect of integrated nutrients on growth and yield of lettuce (two years pooled data)

Treatment	Plant height (cm)	Number of leaves	Leaf length (cm)	Leaf breadth (cm)	Leaf canopy spread (cm)	Leaf area (cm^2)	Leaf area index	Fresh weight (g/plant)	Dry weight (g/plant)	Yield (tonnes/ ha)	Days to market-able maturity	Harvest index
T_1	15.50	17.33	17.07	16.11	17.33	192.33	0.23	87.33	7.70	11.7	62	0.62
T_2	20.58	19.50	19.93	18.39	20.42	313.50	0.40	111.50	10.53	14.9	59	0.62
T_3	21.07	24.33	25.58	25.39	24.96	361.83	0.46	172.67	12.19	23.0	57	0.68
T_4	23.08	26.83	26.91	27.09	28.92	449.83	0.58	196.83	12.87	26.3	53	0.70
T_5	20.42	20.92	23.20	21.41	22.98	350.67	0.45	123.17	11.50	16.4	56	0.58
T_6	21.25	25.83	25.73	25.55	25.79	427.17	0.53	185.33	12.58	24.7	55	0.66
T_7	26.92	29.17	27.64	27.67	29.75	543.33	0.67	206.33	13.85	27.5	53	0.78
T_8	21.50	24.08	23.27	2213	23.75	348.67	0.41	155.17	11.85	20.7	56	0.70
SEd±	0.73	0.78	0.45	0.38	0.97	1.36	0.01	1.57	0.16	0.2	0.47	0.01
CD (P=0.05)	1.97	1.56	1.27	0.91	1.43	5.57	0.03	2.73	0.28	0.4	2.27	0.03

Treatment details are given under Materials and Methods.

of organic manures along with bio-fertilizers have increased the metabolic activity of plants due to the presence of various micronutrients in the early growth stage which in turn improved the overall growth of the plant (Prativa and Bhattarai 2011).

Pooled data analysis for the two consecutive years showed that the leaf length was recorded maximum in T_7 (27.64 cm) and was at par with T_3 (25.58 cm), T_4 (26.91 cm) and T_6 (25.73 cm). Maximum (27.67 cm) leaf breadth was recorded in T_7 which was at par with T_4 (27.09 cm).The increase in availability of nutrients enhanced the growth of the plant and hence the breadth of the lettuce leaf (Islam *et al.* 2019). The integrated use of nutrients resulted in rapid cell division, multiplication and cell elongation in the meristematic region of the plant which promoted vegetative growth of the plant (Yadav *et al.* 2007). The leaf canopy spread, leaf area and leaf area index (LAI) were also recorded highest in T_7, i.e. 29.75 cm, 543.33 cm^2 and 0.67 respectively. Integrated application of inorganic fertilizer, organic fertilizer and biofertilizers resulted in increase in availability of nutrients in the soil and thus providing a balanced C:N ratio and increased translocation of nutrients to the aerial parts for synthesis of protoplasmic proteins and other metabolites increasing the photosynthetic area and leaf spread (Neupane *et al.* 2020). Balanced C:N ratio in soil is important for plant growth because plants utilize nutrients in various ways. Carbon is used for building materials and for energy and nitrogen is used for protein synthesis and growth. Nutrients in balanced amounts for optimum plant growth are supplied by soil with a balanced C:N ratio. Deficiency of nitrogen causes yellowing and stunted growth whereas low carbon causes dark green leaves. Application of NPK @40:20:40 kg/ha+ vermicompost @1 tonnes/ha + PSB, i.e. T_7 recorded the highest fresh weight of 206.33 g per plant followed by T_4 and T_6 with values 196 g and 186 g per plant, respectively. The highest dry weight was also exhibited by the treatment T_7 (13.85 g/plant). The application of nutrients in a balanced way enhanced the photosynthetic activity and transport of photosynthates from source to sink which increased the dry weight of the leaves (Khadse *et al.* 2021). Maximum (27.5 tonnes/ha) yield was observed in the treatment T_7 and was followed by the treatments T_4 (26.3 tonnes/ha) and T_6 (24.7 tonnes/ha) (Fig 1). Similar findings of increased yield with combined application of chemical fertilizers, organic manures and biofertilizers were also reported by Chatterjee (2015). The days to

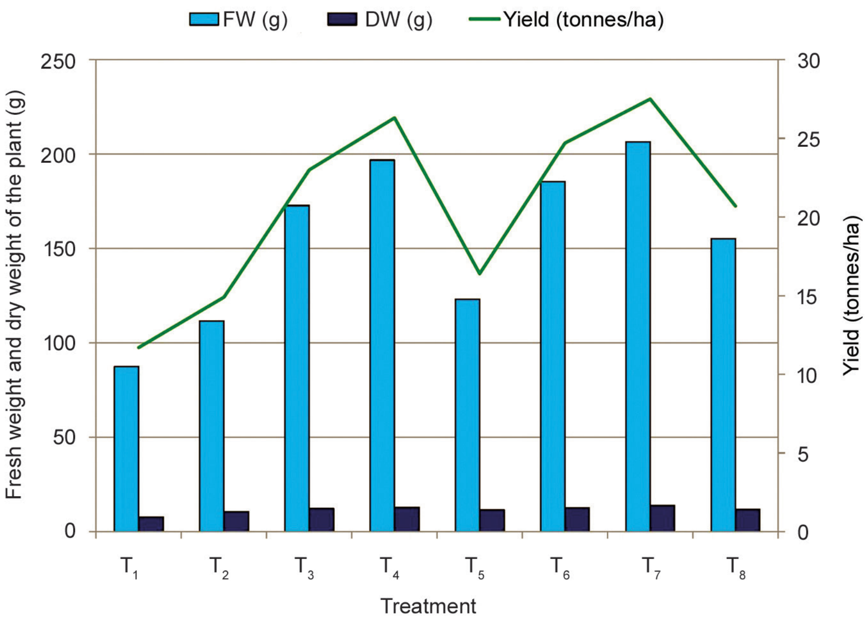

Fig 1 Effect of INM on fresh weight, dry weight and yield of lettuce

Table 2 Effect of integrated nutrients on quality of lettuce

Treatment	Ascorbic acid (mg/100 g)	Reducing sugar (%)	Non reducing sugar (%)	Chlorophyll (mg/100 g)	Nitrogen (%)	Calcium (mg/100 g)	Iron (mg/100 g)	Crude protein (%)
T_1	1.55	4.74	2.02	2.23	0.17	13.67	1.26	1.04
T_2	1.66	4.77	2.15	2.53	0.20	19.00	1.45	1.25
T_3	2.58	6.69	2.54	2.83	0.20	15.20	1.46	1.23
T_4	3.59	6.75	2.96	3.13	0.22	17.67	1.41	1.38
T_5	2.15	6.59	2.65	2.68	0.22	14.45	1.24	1.35
T_6	2.87	6.24	3.80	3.23	0.23	19.33	1.50	1.44
T_7	3.76	6.13	3.98	3.77	0.23	20.67	1.21	1.44
T_8	2.19	6.24	2.07	2.78	0.20	15.08	1.32	1.25
SEd±	0.02	0.16	0.11	0.12	0.01	0.84	0.02	0.07
CD (P=0.05)	0.03	0.35	0.24	0.25	0.02	1.80	0.04	0.14

Treatment details are given under Materials and Methods.

Table 3 Effect of integrated nutrient management on economics of different treatments (two years pooled data)

Treatment	Cost of cultivation (₹/ha)	Yield (tonnes/ha)	Gross return (₹/ha)	Net return (₹/ha)	Benefit-cost
T_1	64,250.00	11.7	117000.00	52750.00	0.8
T_2	66,797.00	14.9	149000.00	82203.00	1.2
T_3	72,797.00	23.0	230000.00	157203.00	2.2
T_4	73,297.00	26.3	263000.00	189703.00	2.6
T_5	72,750.00	16.4	164000.00	91250.00	1.3
T_6	81,797.00	24.7	247000.00	165203.00	2.0
T_7	82,297.00	27.5	275000.00	192703.00	2.3
T_8	93,750.00	20.7	207000.00	113250.00	1.2

*Sale price of lettuce per kg is ₹10.00. Treatment details are given under Materials and Methods

marketable maturity was recorded minimum, i.e. 53 days when integrated application of NPK @40:20:40 kg/ha + vermicompost @1 tonnes/ha + PSB was added whereas it was recorded maximum in control, i.e. 62 days. Application of NPK @40:20:40 kg/ha + vermicompost @1 tonnes/ha + PSB enables the harvesting by around 10 days advance which can be taken as an important point of consideration for integrated nutrient management in lettuce. Maximum harvest index (0.78) was obtained in the treatment T_7 due to higher yield as compared to other treatments.

Effect of integrated nutrient management on quality parameters: The quality parameters of lettuce leaf were influenced by different treatment combinations (Table 2). Ascorbic acid content was found higher with integrated application of organic and inorganic fertilizers as compared to the treatment with inorganic fertilizer alone. Highest ascorbic acid content (3.76 mg/100 g) was recorded in T_7. Due to combined application of fertilizers there was an increase in carbohydrate production, subsequently synthesizing more vitamin C content (Shanu *et al.* 2019). Kumar *et al.* (2015) reported that the enhancement in carbohydrates further increased the ascorbic acid production. Similar findings were also reported by Sharma and Agarwal (2014) in spinach. Reducing sugar and non-reducing sugar content of the leaves were significantly influenced by the combined application of nutrients. Application of FYM in combination with NPK and biofertilizers, i.e. T_4 recorded maximum reducing sugar whereas application of vermicompost in combination with NPK and biofertilizers (T_7) exhibited maximum non-reducing sugar. This might be due to improvement of soil physical properties like bulk density, porosity, water holding capacity, structure, etc and chemical properties like nutrient status, hormone, etc imparted by biological activity of bacteria, fungi, actinomycetes and earthworm (Chattopadhay 1994). Soil porosity is important for plant growth because the pores contain ground water and oxygen. Oxygen is essential for all the plants to carry out the important physiological processes such as respiration. Bulk density is less in soil having higher amounts of organic matter content. Application of biofertilizer improves water retention capacity, increases porosity and lowers the bulk density of soil (Demir 2020). Inorganic and organic fertilizers in combination with biofertilizers are essential for improvement of soil physical properties and enhance crop growth and uptake of nutrients. It also resulted in higher values for quality and yield traits. Arvind *et al.* (2012) reported that conversion of starch and polysaccharides into simple sugar and its storage was responsible for the increase in reducing and non-reducing sugar content.

The highest chlorophyll content was reported in T_7 whereas the lowest chlorophyll content was reported in T_1. Similar findings were reported by Sunanda *et al.* (2014) in Kasuri methi where high chlorophyll content was found due to increased availability of macro and micro nutrients which would retard leaf senescence and improve the photosynthates assimilation. Leaf nitrogen content was reported highest in treatment T_7 and T_6 which was at par with T_4 and T_5 because the integrated nutrients stimulate plant growth and nutrient uptake. The increased nitrogen might be due to additional N in the form of inorganic fertilizer together with organic fertilizers which enhanced the N availability to crop. Similar results were reported by Worthington (2001) in cabbage. Further, the integrated application of fertilizers and manures might have reduced the nitrogen losses, improved the fertilizer use efficiency and thus the availability of N. The leaf calcium content was recorded highest in T_7 which was at par with T_2 and T_6. The increase in calcium content of leaves is due to increase in uptake of micro and macronutrients. The presence of organic acids in vermicompost might have released calcium from the exchange sites present in the soil and thus increased the availability of calcium in the plant (Sanjeevkumar 2014).The leaf iron content was recorded highest in T_6. The high iron content in the leaves of lettuce is due to application of vermicompost which increases the availability of micronutrients. The organic acids such as humic acid, malonic acid, fumaric acid, succinic acid are produced during decomposition of vermicompost and these organic acids act as chelating agents by encapsulating metallic ions like calcium, magnesium, iron, zinc, manganese, etc making them more accessible for plant use (Chopra *et al.* 2017).

The highest crude protein content was reported in the treatments T_6 and T_7 which were at par with T_4 and T_5. The high crude protein content might be due to easy availability of nutrients, balanced C:N ratio in soil which increased the vegetative growth and the photosynthetic activity of the plant which resulted in intense protein synthesis and its better uptake and assimilation (Sanjeevkumar 2014). Integrated application of nutrients enhanced N content in leaves and as a result the amount of crude protein increased.

From the investigation, it can be concluded that the application of inorganic fertilizer (40:20:40 NPK kg/ha) with vermicompost (1 tonnes/ha) and PSB exhibited maximum performance for growth and quality traits in lettuce. The highest net return (₹192703.00) was obtained in the treatment T_7 with a benefit-cost ratio of 2.3 (Table 3). However, the highest benefit-cost ratio was exhibited by the treatment T_4 (2.6) with a net return of ₹189703.00 due to lower cost of production in T_4 (40:20:40 NPK kg/ha + FYM 2 tonnes/ha + PSB) as compared to the treatment T_7.

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