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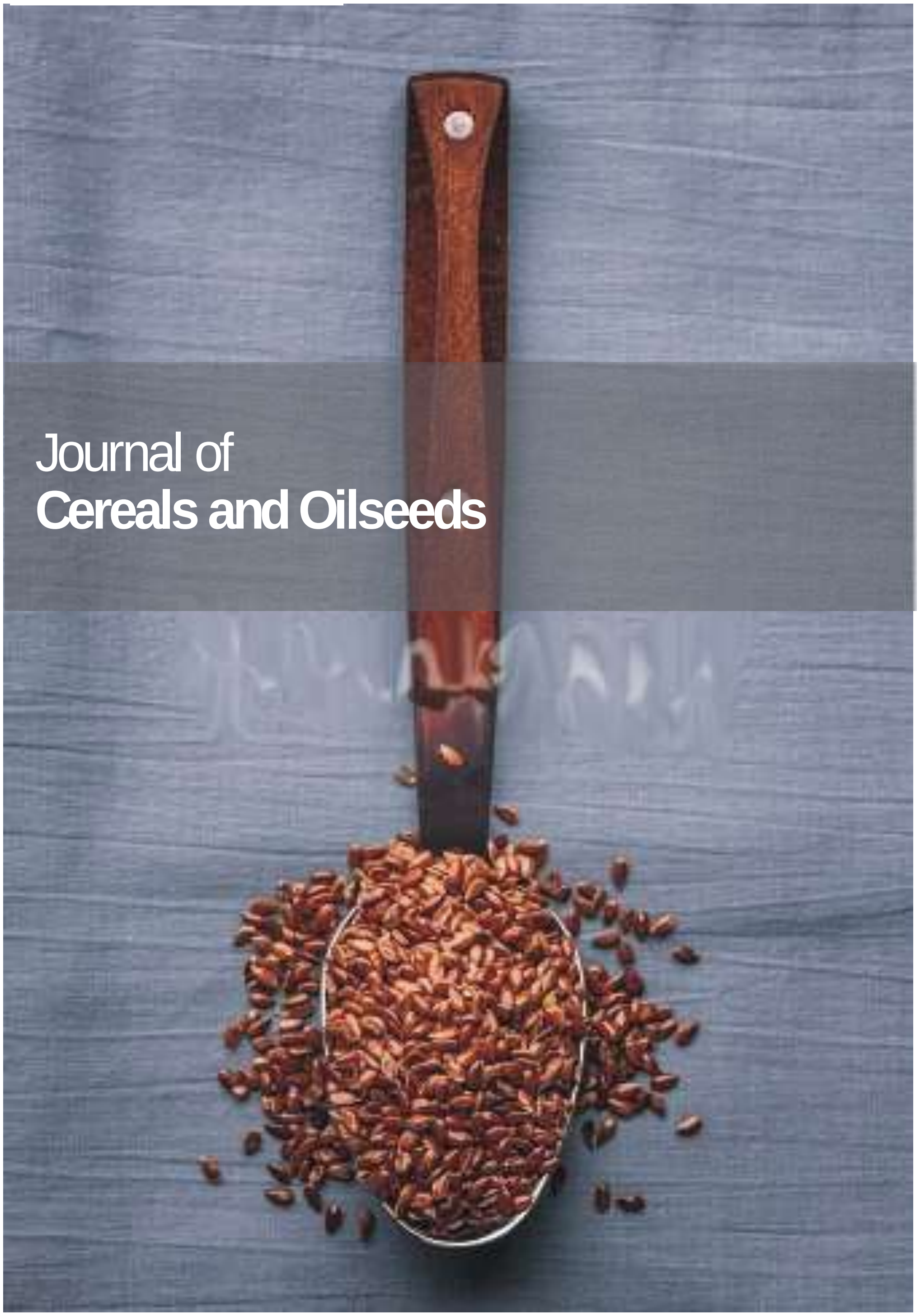

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Full Length Research Paper

Impacts of various fertilizer combinations onto some agronomical traits of rice (*Oryza sativa* L.) grown employing hazton methods

Hanida Robbani[1], Widyatmani Sih Dewi[2], Haryuni Prasojo[3] and Supriyadi Darsowiyono[2*]

[1]Department of Agrotechnology, Faculty of Agriculture, University of Sebelas Maret, Surakarta, Indonesia.
[2]Department of Soil Science, Faculty of Agriculture, University of Sebelas Maret, Surakarta, Indonesia.
[3] Department of Agrotechnology, Faculty of Agriculture, University of Tunas Pembangunan, Surakarta, Indonesia.

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Hazton cultivating methods is an engineered rice cultivation method using old seeds aged 25-30 days after seedling with 20-30 stems per planting hole. The old seeds have several advantages: their harvest period is faster, and their plant adapts easily and minimize the embroidery. The objective of this study was to determine the effect of various fertilizer combinations and *Jajar legowo* planting system on the growth and yields of rice on cultivating Hazton methods. This research was carried out on July-October 2017 located in rice field of Tunjung Semi Village, Sambungmacan Sub-district, Sragen Regency, Central Java, Indonesia. Randomized Complete Block Design (RCBD) was used for this research with two treatment factors namely Fertilization (P) which consists of P1 (N 179,34 kg.ha^{-1}, P_2O_5 149,94 kg.ha^{-1}, K_2O 132,3 kg.ha^{-1}, S 29,4 kg.ha^{-1}), P2 (N 115 kg.ha^{-1}, P_2O_5 27 kg.ha^{-1}, K_2O 30 kg.ha^{-1}), P3 (N 103,5 kg.ha^{-1}, P_2O_5 9 kg.ha^{-1}, K_2O 18 kg.ha^{-1}, Manure 2 ton.ha^{-1}) and the Planting Method (H) consists of H1 (Hazton *Jajar legowo* 6:1) and H2 (Hazton Conventional). The inspected characteristics are plant height, number of tillers, content and uptake of N, P, K, spikelet fertility, grains moisture, weight of 1000 grains and rice production. The treatment P3 resulted the highest weight of 1000 grains. The treatment H1 resulted in higher rice production than the treatment H2.

Key words: Cultivation method, planting system, inorganic fertilizer, manure.

INTRODUCTION

Rice (*Oryza sativa* L.) is an important crop in Indonesia because rice is the main staple food in the country (Widyastuti et al., 2015). Moreover, rice also has been the staple food of more than half of the world's population. Indonesian people consumes rice at approximately 85,045 kg per capita per year in 2015 (CBS, 2017c). Indonesian's population density in 2015 was 134 people per km^{-2}. The number has increased from the previous year with 132 people per km^{-2} (CBS, 2017b). The increasing number of people causes the

*Corresponding author. E-mail: supriyadi_uns@yahoo.com. Tel: 08179488860.

need for more production of rice. The conversion of industries in Indonesia reaches more than 110.000 ha per year. The less agricultural land area, the most realistic effort to increase rice production is by increasing the productivity of agricultural land.

Hazton cultivating technology is an engineered rice cultivation introduced in 2012 in West Kalimantan by Ir. Hazairin, M.S. Head of Department of Food Crops and Horticulture of West Kalimantan Province and Anton Komaruddin SP, M.Si. staff at the Office of Food Crops and Horticulture West Kalimantan Province. Hazton Technology is a planting technique which relies on using old seeds aged 25 to 30 days after seedling (DAS) with 20 to 30 stems per planting hole. Hazton Cultivating Methods can increase the production of Cibogo and Inpari rice variety in West Kalimantan Province (Wibowo et al., 2015).

Java province is the most crowded province in Indonesia. The conversion of agricultural land is increased every year. Hazton technology is expected to increasing the productivity of rice in Java, despite the agricultural land decreased. The test results of Hazton technology delivering diverse productivity ranged from 4 to 9 ton.ha^{-1} in several regions (Wibowo et al., 2015). Hazton Cultivation Technology has several advantages namely the harvest period is faster, the plant is easy to adapt and not easy to stress, minimize the embroidery and high grain quality. However, Hazton Cultivation Technology also has some disadvantages that requires additional fertilization and being susceptible to disease disorders.

The number of seeds 20-30 stems per planting hole makes the plants to be more dense and lush. Lush plant conditions pave way for diseases. Higher plant density leads to competition for sunlight, nutrients, oxygen and water (Bozorgi et al., 2011). The lack of sunlight, nutrients, oxygen and water will be an obstacle in increasing rice yields. This can be overcome by changes in the management of affected resources such as nutrition, air, water, soil microorganism and solar energy (Ceesay et al., 2006). Balanced fertilization and *Jajar legowo* planting system in this study is expected to overcome the weaknesses of Hazton cultivation method.

Jajar legowo planting system is a planting system that uses one blank row between two rows of rice plant. The blank row given after two or more rows of rice plants. The blank row is a blank space without a plantation. The width of blank row is two times plant spacing. The aims of *Jajar legowo* planting pattern is to maximize the absorption of sunlight by plants. Easier absorption of sunlight and diffusion of CO_2 causes the process of photosynthesis to be more optimal (Lin et al., 2009). Moreover, the plants grown in optimum distances will grow better because there is less competition for nutrients and water (Sohel et al., 2009).

Jajar legowo system also play role in reducing pests and diseases because the land is relatively open. Relatively open land decreases humidity and resulted in lack of diseases, and blank row in *Jajar legowo* facilitates the process of plant maintenance (Qibtiyah and Amiroh, 2015). Another advantage of *Jajar legowo* is that the blank row does not reduce the plant population and does not decrease the production. *Jajar legowo* planting system actually increases the plant population by 15 to 25% more than tile system population, as in *Jajar legowo* 2:1 dan 4:1 (Darmawan, 2016).

Balanced fertilization is a mixed fertilization of organic and inorganic fertilizers. The merger of organic and inorganic fertilizers aims to meet the nutritional needs of the plant (Asbur and Purwaningrum, 2015). Organic matter affects the physical, chemical and biological properties of the soil. Organic matter serves as a source of plant nutrients, providing food and energy for beneficial organism, improves soil structure, water holding capacity and prevents erosion (Sultana et al., 2015). In addition, the advantage of organic waste applications in agriculture is that organic waste can provide some nutrients for plants with little additional cost (Myint et l., 2010). Manure is kind of organic matterial that affects soil productivity. The paddy fields with manure added as crop nutrient source beside inorganic fertilizer had higher soil quality index (Supriyadi et al., 2017).

MATERIALS AND METHODS

Experimental design

The experiment used Randomized Complete Block Design (RCBD) with two factors, that is Fertilization (P) and Planting Method (H). The fertilization treatment (P) consisting of:

P1: N 179,34 kg.ha^{-1}, P_2O_5 149,94 kg.ha^{-1}, K_2O 132,3 kg.ha^{-1}, S 29,4 kg.ha^{-1} (according to local farmer's habits)
P2: N 115 kg.ha^{-1}, P_2O_5 27 kg.ha^{-1}, K_2O 30 kg.ha^{-1} (Indonesian Agricultural Ministry, 2007)
P3: N 103,5 kg.ha^{-1}, P_2O_5 9 kg.ha^{-1}, K_2O 18 kg.ha^{-1}, Manure 2 ton.ha^{-1} (balanced fertilization) (Indonesian Agricultural Ministry, 2007)
The planting method treatment (H) consisting of:
H1: Hazton *Jajar legowo* 6:1
H2: Hazton Conventional
From these two factors, 6 treatments combinations were collected, namely H1P1, H1P2, H1P3, H2P1, H2P2, H2P3. The treatments combinations replicated 4 times.

Field work

The research was carried out from July to October 2017 located in rice field of Tunjung Semi Village, Sambungmacan Sub-district, Sragen Regency, Central Java, Indonesia. The geographical location of the research is 7°22'49.7" LS and 111°5'37.3" BT. The treatment plots size was 5 m × 3 m, and the number of plots is 24. The rice planted was IR64 variety with the plant spacing is 25 cm × 25 cm. The planting method treatment devided into two, H1 (Hazton *Jajar legowo* 6:1) and H2 (Hazton Conventional). The treatment H1 (Hazton *Jajar legowo* 6:1) is combination between Hazton method (old seeds aged 30 DAS with the number of seeds is 15 per planting hole) and *Jajar legowo* 6:1 (blank space given every after 6 rows of rice plant). The treatment H2 (Hazton Conventional) is only using Hazton method (old seeds aged 30 DAS with the number of

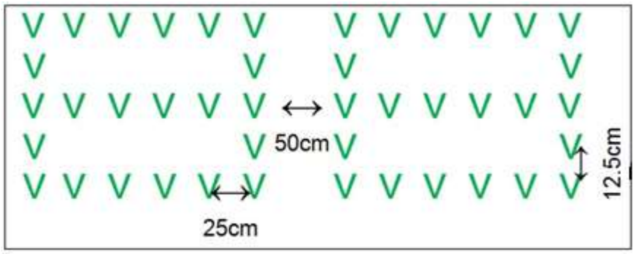

Figure 1. H1 (Hazton Jajar Legowo 6:1) plot's design.

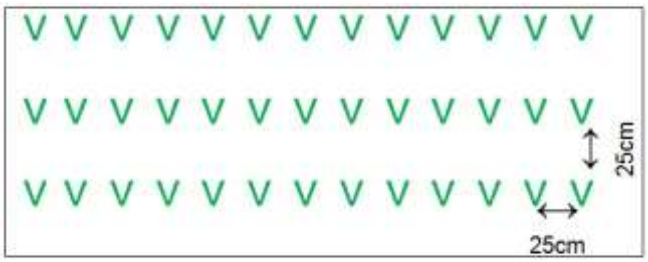

Figure 2. H2 (Hazton conventional) plot's design.

seeds is 15 per planting hole) without combination. Afterwards, the fertilization treatment (P) given in the two stages. The first fertilization was done 7 DAP and the second fertilization was done after 30 DAP. Manure is given at 2 weeks before planting (Figures 1 and 2).

Soil and plant tissue analysis

The analysis of the soil and plant tissue was carried out in Chemistry and Soil Fertility Laboratory and Ecology Management and Plant Production Laboratory of Agriculture Faculty of Sebelas Maret University Surakarta, Indonesia. The soil analysis of the location of the research contains actual pH analysis (H_2O), Cation Exchange Capacity (CEC), N-total, P-available, K-exchange, organic material and soil texture. The soil N-total was analyzed by *Kjeldahl* method, P-available by Olsen method, CEC and K-exchange using NH_4Oac 1 M, pH 7.0 extract, C-organic by Walkey and Black method, and soil texture was analyzed using Hidrometer method. The scoring for each characteristics according to Eviati and Sulaeman (2009). Observation of plant tissue variables consisted of N, P, K content on crop tissue and N, P, K uptake. This analysis was performed when the plant was in the maximum vegetative phase. Content of N on crop tissue was analyzed by *Kjeldahl* method, content of P and content of K were analyzed using HNO_3 and $HClO_4$ extract (Eviati and Sulaeman, 2009).

The observation of plant growth and yields

The observation of plant vegetative growth variables consisted of plant height, number of tillers, and number of productive tillers was measured at 15, 30, 45 and 85 DAP. The observation of rice yield variables consisted of the spikelet fertility % $(SF = \frac{\Sigma filled\ grains}{\Sigma grains\ per\ plot}\ x\ 100\%)$, the weight of 1000 grains, the moisture % of grain $(MG = \frac{the\ weight\ of\ (wet\ grains - dry\ grains)}{the\ weight\ of\ wet\ grains}\ x\ 100\%)$, the grains production per plot and the grains production per hectare was measured after harvest.

Statistical analysis

SPSS 22.0 statistical package was used to analyzed the data. Data were analyzed by variance analysis using F-test at 5% level. If there is a significant effect then continued comparison analysis using *Duncan Multiple Range Test* (DMRT) at 5% level. The relationship between observed variables was analyzed by *Pearson*'s correlation test.

RESULTS AND DISCUSSION

Sites characteristic

The soil texture at the research location was clay with composition of sand 3.46%, dust 10.38% and clay 86.15%. The value of Cation Exchange Capacity (CEC) of soil is 37.50 cmol(+).kg^{-1} classified as high. The value of soil pH is 6,27 classified as a bit acid. Organic material in the research location is 1.35% classified as low. Content of soil N-total (0.42%) is medium. Content of soil P-available (6,84 ppm) is low and content of soil K-exchange which was 0.25 cmol(+).kg^{-1} is also classified as low (Table 1). The relatively low nutrient condition at the research location requires fertilizer to support the growth and development of rice crops. Plants require 165 kg.ha^{-1} N, 19 kg.ha^{-1} P and 112 kg.ha-1 K to produce an average of 6 tons.ha-1 rice (Dobermann and Fairhurst, 2000). Organic material in the research location is low, it also requires organic subtances to support the soil. C-organic has influences to the soil quality because C-organic showed a significant correlation to all of physical soil properties (Supriyadi et al., 2014).

The vegetative growth

The result of variance analysis using F-test level 5% showed that the fertilization treatment had a very significant effect on the plant height and the number of tillers. The planting method treatment had a very significant effect on the plant height, but had no significant effect on the number of tillers. The interaction between fertilization treatment and planting method had no significant effect on the plant height and the number of tillers.

In general, the best plant growth was recorded in the treatment P1 (N 179.34 kg.ha^{-1}, P_2O_5 149.94 kg.ha^{-1}, K_2O 132.3 kg.ha^{-1}, S 29.4 kg.ha^{-1}). The second best plant growth was recorded in the treatment P3 (N 103.5 kg.ha^{-1}, P_2O_5 9 kg.ha^{-1}, K_2O 18 kg.ha^{-1}, Manure 2 ton.ha^{-1}) (Figure 3). The result of the plant height in the treatment P1 is 98.18 cm, but the number of tillers on the treatment P1 shows no significant different with the treatment P3. The number of tillers on the treatment P1 is 20.27 while the treatment P3 is 20.91 (Table 2).

Table 1. Results of soil analysis of the research location.

S/N	Soil Characteristics	Results	Unit	Level
1.	pH H_2O	6.27	-	A bit acid*
2.	CEC	37.50	cmol(+).kg^{-1}	High*
3.	N-Total	0.42	%	Medium*
4.	P-Available	6.84	ppm	Low*
5.	K-Exchange	0.25	cmol(+).kg^{-1}	Low*
6.	Organic Material	1.35	%	Low*
7.	Soil Texture			*Clay**
	Sand	3.46	%	
	Dust	10.38	%	
	Clay	86.15	%	

Source: Analysis results of Soil Chemistry and Fertility Laboratory of Agriculture Faculty, Sebelas Maret University, Surakarta, 2017.
Note: *Level according to (Eviati and Sulaeman, 2009).

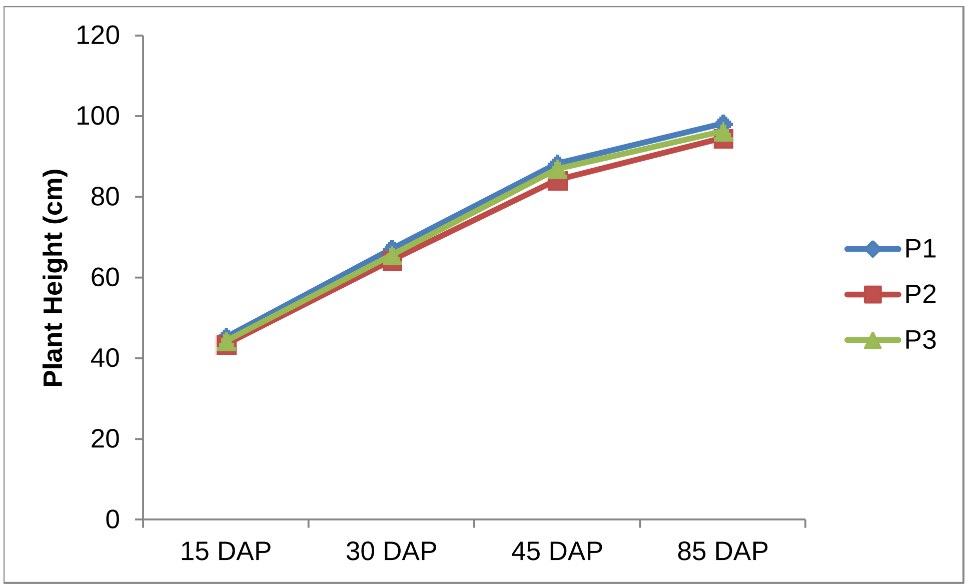

Figure 3. The effect of fertilizer treatment to the plant height.

Table 2. The effect of fertilization treatment and planting method to the plant height and the number of tillers.

Treatment	Plant height (cm)	Number of tillers at 45 DAP	Number of productive tillers
Fertilization			
P1	98.18^{a}	20.27^{a}	19.64^{a}
P2	94.60^{c}	17.91^{b}	17.53^{b}
P3	96.30^{b}	20.91^{a}	20.61^{a}
Planting method			
H1	95.20^{b}	19.50	19.14
H2	97.52^{a}	19.89	19.39

Note: The numbers followed by the same letters show difference no significant in the Duncan test level 5%.

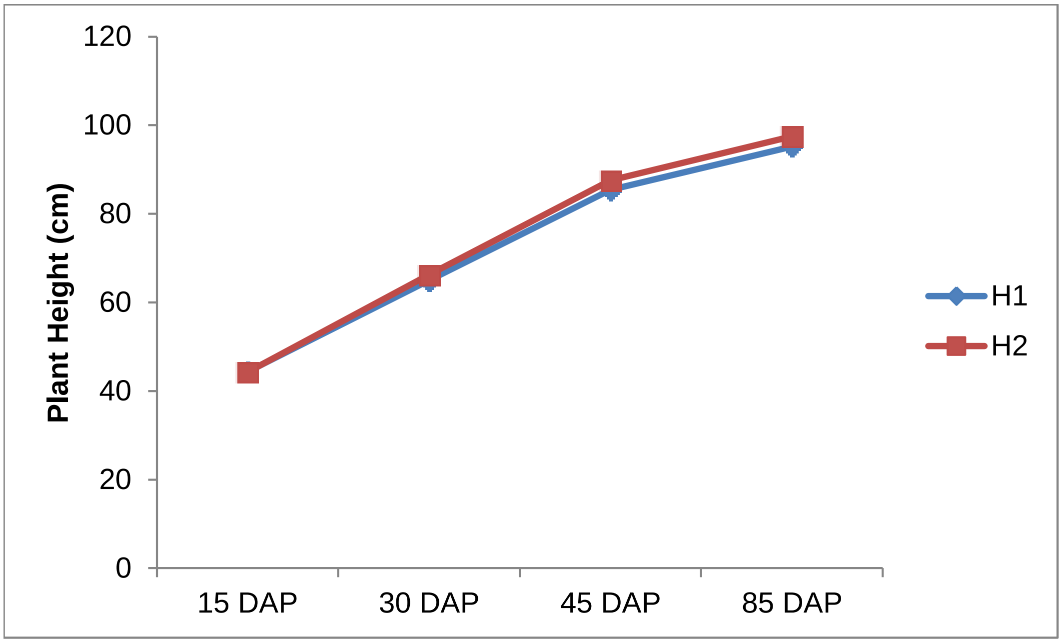

Figure 4. The effect of planting method treatment to the plant height.

The treatment P1 had highest dose of inorganic fertilizer, it affected the plant height. The treatment P3 still had lower plant height than the treatment P1. Nevertheless, the treatment P3 can increase the number of tillers comparable to the treatment P1. According to the previous study by Santosa and Suryanto (2015) about rice growth using inorganic and manure fertilizer resulted that the application of inorganic fertilizer (100 kg.ha^{-1} N, 50 kg.ha^{-1} P_2O_5 , 70 kg.ha^{-1} K_2O) is increasing the growth of the plant more than by using 10 ton.ha^{-1} manure. The other study by Sudarsono et al. (2014) resulted that the application of 10 ton.ha^{-1} cow manure increased number of tillers, compared with no manure. The combination of manure and inorganic fertilizer can provide complete macro nutrients (N, P, K, Ca, Mg, S) and micro nutrients in equal quantities for the growth and development of plant.

The plant growth on the treatment H2 (Hazton Conventional) shows better result than the treatment H1 (Hazton *Jajar legowo* 6:1) (Figure 4). The plant height on the treatment H2 is 97.52 cm while the plant height on the treatment H1 is 95.20 cm (Table 2). The planting method on treatment H1 (Hazton *Jajar legowo* 6:1) give blank space between plant rows, but the plant populationinside the rows will increase. The increased population in *Jajar legowo* 6:1 is 14.29% from the conventional system. Increasing plant density had an effect on the plant growth. The rate of photosynthesis is strongly influenced by the spread of sunlight in the plant canopy, and the presence of shade leaves will reduce the rate of photosynthesis. The lower plant density resulted the better plant growth (Asmamaw, 2017).

The content of N, P, K on crop tissue and N, P, K uptake

The result of variance analysis using F-test level 5% showed that the fertilization treatment had a significant effect on the content of P on crop tissue and had a very significant effect on the content of N and the content of K. The fertilization treatment also had a very significant effect on the uptake of N, P and K per plant. The planting method treatment had no significant effect on the content of N, P, K on crop tissue and the uptake of N, P, K. The interaction between fertilization and planting method treatment also had no significant effect on content of N, P, K on crop tissue and N, P, K uptake.

The highest content of N and K on crop tissue was recorded in the treatment P1 (N 179.34 kg.ha^{-1}, P_2O_5 149.94 kg.ha^{-1}, K_2O 132.3 kg.ha^{-1}, S 29.4 kg.ha^{-1}). The highest N and K uptake also recorded in the treatment P1. However, the content of P on crop tissue in the treatment P1 had no significant difference to the treatment P3 (N 103.5 kg.ha^{-1}, P_2O_5 9 kg.ha^{-1}, K_2O 18 kg.ha^{-1}, Manure 2 ton.ha^{-1}), and so is the uptake of P (Table 3). The single inorganic fertilizer had highest single primary nutrient, above all the treatment P1 had highest dosage of N, P_2O_5 and K_2O. The dosage of inorganic fertilizer affected the nutrient uptake. The inorganic fertilization itself caused the highest nutrient uptake by rice plant on the maximum vegetative phase, compared to the organic fertilization (Azizah et al., 2013). The opposite result showed in the research by Jeon (2012), increasing level of N application had no effect on the N uptake of plant. Despite of that, the treatment P3

Table 3. The effect of fertilization treatment to the content of N, P, K on crop tissue and the uptake of N, P, K.

Fertilization Treatment	Content			Nutrient uptake (g per plant)		
	N (%)	P (%)	K (%)	N	P	K
P1	3.01[a]	0.43[a]	1.83[a]	1.09[a]	0.16[a]	0.67[a]
P2	2.25[b]	0.39[b]	1.47[b]	0.80[c]	0.14[b]	0.52[b]
P3	2.41[b]	0.42[ab]	1.48[b]	0.91[b]	0.16[a]	0.56[b]

Note : The numbers followed by the same letters show difference no significant in the Duncan test level 5%.

Table 4. The effect of fertilization treatment to the rice yields component.

Fertilization treatment	Spikelet fertility (%)	Moisture of grain (%)	Weight of 1000 grains (g)
P1	85.62[b]	24.37[a]	35.53[b]
P2	87.01[a]	25.08[b]	35.47[b]
P3	88.95[a]	25.06[a]	35.67[a]

Note: The numbers followed by the same letters show difference no significant in the Duncan test level 5%.

can increase the uptake of P. The treatment P3 contains manure that affects soil productivity. Kasim et al. (2011) stated that the organic subtances could enhance the nutrient uptake of plant. Organic material can increase the availability of P from mineral. The phosphorus elements in the soil can also be found in the form of Al-P, Fe-P and Ca-P. The decomposition products from manure such as humic acids is able to suppress the fixation of P so as to decrease the Al-P and Fe-P form, and increase the available-P levels (Zhang et al., 2009).

The rice yields component

The result of variance analysis using F-test level 5% showed that the fertilization treatment had a very significant effect on the spikelet fertility (%), the moisture of grain (%) and the weight of 1000 grains. The planting method treatment had no significant effect on the spikelet fertility (%), the moisture of grain (%) and the weight of 1000 grains. The interaction between fertilization and planting method treatment also had no significant effect on the spikelet fertility (%), the moisture of grain (%) and the weight of 1000 grains.

The treatment P3 (N 103.5 kg.ha^{-1}, P_2O_5 9 kg.ha^{-1}, K_2O 18 kg.ha^{-1}, Manure 2 ton.ha^{-1}) showed the highest result in the weight of 1000 grains. The spikelet fertility (%) in the treatment P3 had no significant different to the treatment P2 and the moisture of grain (%) in the treatment P3 had no significant different to treatment P1 (Table 4). The weight of grain depends on the dry matter accumulation in grains. Dry matter accumulation depends on the processes of carbon and nitrogen assimilation pre-anthesis and translocation post-anthesis (Tang et al., 2009). If the process goes well then the filled grains will take the maximum place. The carbon and nitrogen assimilation affected by the availability of nutrients during reproductive phase. Pan et al. (2009) stated that the mix of inorganic and organic can increase the efficiency of fertilization. Manure can increase the cations holding capacity which is affected the nutrient availability. The higher the cations holding capacity the lower nutrient leaching occured. There is a positive connection between organic material given with the availability of plant nutrients (Ming et al., 2011).

The result of variance analysis using F-test level 5% showed that the treatment fertilization had a very significant effect on the production of grains per plot and the production of grains per hectare. The planting method treatment also had a very significant effect on the production of grains per plot and the production of grains per hectare. While, the interaction between fertilization and planting method treatment had no significant effect on the production of grains per plot and the production of grains per hectare.

The production of grains per plot on treatment P1 (N 179.34 kg.ha^{-1}, P_2O_5 149.94 kg.ha^{-1}, K_2O 132.3 kg.ha^{-1}, S 29.4 kg.ha^{-1}) was not significantly different with the treatment P3 (N 103.5 kg.ha^{-1}, P_2O_5 9 kg.ha^{-1}, K_2O 18 kg.ha^{-1}, Manure 2 ton.ha^{-1}). The production on the treatment plot P1 was 16,16 kg while treatment plot P3 was 16.63 kg. The treatment P1 and P3 also had no significant difference to the production of grains per hectare, the treatment P1 produce 9.79 ton.ha^{-1} while treatment P3 produce 10.08 ton.ha^{-1}. The lowest grains production was the treatment plot P2 (N 115 kg.ha^{-1}, P_2O_5 27 kg.ha^{-1}, K_2O 30 kg.ha^{-1}). The production of grains on treatment plot P2 was 14,95 kg, while the production per hectare was 9,06 ton.ha^{-1} (Table 5).

The production of grains on the treatment plot H1(Hazton Method *Jajar legowo* 6:1) is higher than the treatment plot H2 (Hazton Conventional). The treatment H1 produced grains 16.48 kg per plot, while per hectare produce 9.99 ton.ha^{-1} (Table 5). Plant population on the

Table 5. The effect of fertilization treatment dan planting method to the production of grains.

Treatment	Grains production	
	kg per plot	ton.ha^{-1}
Fertilization		
P1	16.16^{a}	9.79^{a}
P2	14.95^{b}	9.06^{b}
P3	16.63^{a}	10.08^{a}
Planting method		
H1	16.48^{a}	9.99^{a}
H2	15.34^{b}	9.30^{b}

Note: The numbers followed by the same letters show difference no significant in the Duncan test level 5%.

Table 6. The correlation of N,P,K content and N,P,K uptake to vegetative growth and rice yields component.

	PH	NT	NPT	N	P	K	NU	PU	KU	SF	MG	1000G
PH	1	0.53**	0.30	0.45*	0.21	0.46*	0.48*	0.23	0.53**	-0.03	0.40	0.31
NT		1	0.96**	0.37	0.44*	0.18	0.46*	0.51*	0.31	0.04	0.63**	0.46*
NPT			1	0.28	0.42*	0.08	0.37	0.49*	0.20	0.18	0.54**	0.47*
N				1	0.46*	0.72**	0.98**	0.44*	0.73**	-0.40	0.21	0.02
P					1	0.256	0.53**	0.94**	0.35	-0.15	0.10	0.09
K						1	0.67**	0.20	0.98**	-0.35	0.24	0.01
NU							1	0.55**	0.72**	-0.29	0.29	0.15
PU								1	0.34	-0.04	0.17	0.27
KU									1	-0.25	0.32	0.15
SF										1	0.19	0.22
MG											1	0.52**
1000G												1

Note: **= correlated very real, *= correlated real. N = Content of N, P = Content of P, K = Content of K, NU= N Uptake, PU = P Uptake, KU = K Uptake, PH = Plant Height, NT = Number of Tillers, NPT = Number of Productive Tillers, N = Content of N, P = Content of P, K = Content of K, NU= N Uptake, PU = P Uptake, KU = K Uptake, SF= Spikelet Fertility (%), MG= Moisture of Grain (%), 1000G= Weight of 1000 Grains

treatment H1 is heigher than the treatment H2, this cause the grains production per plot higher than the treatment H1, and the production per hectare will also be higher. Increasing plant density significantly decreased the number of panicles per hill but significantly increased the number of panicles per m^2 (Matsumoto et al., 2017).

The plant height positively correlated with the content and the uptake of N and K. The number of productive tillers positively correlated with the content and the uptake of P (Table 6). Positive correlations indicate that as the size or height of a trait increases, it will always be followed by an increase in the magnitude or height of the other. The higher the contents of N and K on crop tissue, the higher the plant height. The higher the contents of P on crop tissue, the higher the number of productive tillers. The nutrient content and uptake by plant determines the vegetative growth. N, P and K nutrient elements are the primary nutrients needed by plants in relatively large quantities compared to other elements (Marlina et al., 2014). Similiary with the study by Hwang et al. (2012), at the moment that content of P on stem increased significantly under high N-P fertilization treatment, the number of tillers also increased. Futhermore, plant's vegetative growth determines the component of yields of rice. Maximum growth will produce maximum plant products as well. The number of tillers positively correlated with the moisture of grain and the weight of 1000 grains (Table 6).

Conclusions

High dosage of inorganic fertilizer (N 179.34 kg.ha^{-1}, P_2O_5 149.94 kg.ha^{-1}, K_2O 132.3 kg.ha^{-1}, S 29.4 kg.ha^{-1}) resulted in best plant height and content of N and K on crop tissue. Balanced fertilization (N 103.5 kg.ha^{-1}, P_2O_5 9 kg.ha^{-1}, K_2O 18 kg.ha^{-1}, Manure 2 ton.ha^{-1}) resulted in highest weight of 1000 grains and can replace the use of high dosage inorganic fertilizer (N 179.34 kg.ha^{-1}, P_2O_5 149.94 kg.ha^{-1}, K_2O 132.3 kg.ha^{-1}, S 29.4 kg.ha^{-1}) on the number of tillers and the grains production. Hazton *Jajar* Hazton Conventional.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Effect of integrated nutrient management (INM) modules on late sown Indian mustard [*B. juncea* (L.) Cernj. & Cosson] and soil properties

H. Singh[1], R. P. Singh[2], B. P. Meena[3]*, B. Lal[4], M. L. Dotaniya[2], A. O. Shirale[2] and K. Kumar[5]

[1]Department of Agronomy, PAU, Ludhiana, Punjab, India.
[2]Department of Agronomy, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar-263 145 (U.S. Nagar), Uttarakhand, India.
[3]ICAR- Indian Institute of Soil Science, Bhopal Madhya Pradesh, India.
[4]ICAR- National Rice Research Institute, Cuttack, Odisha, India.
[5]IICAR-Indian Institute of Soil and Water Conservation, Research Centre, Kota, Rajasthan, India.

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A field experiment was conducted to assess the effect of integrated nutrient management (INM) modules on yield and soil properties in late sown Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson.]. In this study, 16 INM module combinations of organic (Farm yard manure and vermicompost), inorganic and biofertilizers were used. The experiment was laid out in randomized block design (RBD) with three replications. The numbers of secondary branches were conspicuously higher than primary and tertiary branches and these also bear higher number of siliquae/branch. The contribution of secondary branches was highest in seed yield of mustard. Integrated use of 100% recommended fertilizer dose (RDF) along with organic sources of nutrients resulted in significantly higher number of branches/plant, siliqua/branch, seeds/siliquae and seed yield of mustard as compared to application of 100% RDF (NPK) alone. The total N, P and K uptake by the crop ranged between 76.1 kg/ha in control and 187.2 kg/ha in 100% recommended dose of fertilizers (RDF) + FYM 5 t/ha + vermicompost (VC) 2.5 t/ha + *Azotobacter*. Integration of inorganic and organic sources of nutrients improved the soil organic carbon (SOC) content, availability of soil nutrient status (N, P and K), microbial biomass carbon (MBC) and dehydrogenase activity (DHA) in soil, whereas the use of chemical fertilizer alone showed a pronounced decline of these parameters.

Key words: Integrated nutrient management, Indian mustard, seed yield, oil content, soil health.

INTRODUCTION

Indian mustard occupies more than 70% of the area under rapeseed-mustard group of crops grown in India. The production of rapeseed mustard in India was 8.0 million tonnes with productivity of 1188 kg/ha and area harvested 6.7 million hectares (Economic survey, 2014-15). Generally, pulse and oilseed crops are raised under

*Corresponding author. E-mail: bharatmeena24@gmail.com.

rainfed conditions with low input and poor management practices leading to lower productivity level (Lal et al., 2015). Yield potentials of the crop, can be realized by balanced and efficient use of organic and inorganic sources of nutrient (Meena et al., 2016) and also use of suitable agronomic package practices to crop. Imbalanced nutrition is one of the important constraints towards higher mustard productivity, oil content and other quality parameters (Lal et al., 2016). Intensification of agriculture coupled with use of high analysis fertilizers, deprived of secondary and micronutrients, has led to widespread deficiency of these nutrients which has further aggravated the situation because of restricted or no application of organic manures. The deficiency of sulphur, zinc and boron is very common in many states. In Uttar Pradesh, 53% of the soils are deficient in sulphur, 60% deficient in zinc and 12% deficient in boron (Anonymous, 2014). Nutrient indexing work on soils and crops done at the Pantnagar revealed that negative balance of sulphur, zinc and boron is becoming evident in *Tarai* region (Srivastava et al., 2006).

Rapeseed-mustard requires relatively large amount of these nutrients for realization of yield potential but inadequate supply often leads to low productivity. Hence, it becomes imperative to increase crop productivity to provide balanced and adequate nutrition through organic and inorganic sources. Use of total organic or inorganic nutrient sources has few limitations. Therefore, judicious use of organic and inorganic sources of nutrients is needed for enhancing productivity of rapeseed-mustard. Integrated use of organic and inorganic fertilizers not only ensures availability of all the essential plant nutrients but also improves the soil chemical, biological properties and crop productivity ((Thakur et al., 2009; Meena et al., 2015).

Use of farm yard manure (FYM), vermicompost (VC) and bio-fertilizers like *Azotobacter* in judicious combination with fertilizers can facilitate profitable and sustainable production and are found to improve physical, chemical and biological soil properties (Shroff and Devasthali, 1992). Similarly, Meena et al. (2014) reported that soil quality also improved with the application of organic manures like FYM, leaf compost and VC. In *Tarai* region of Uttarakhand and western UP, the mustard crop is mainly sown late after harvest of rice under rice-mustard-sugarcane cropping system. The yield levels are low under late sown condition. The technologies are available on nutrient management particularly as integrated nutrient management in normal sown condition in mustard. But very little information is available on organic and inorganic nutrient management in late sown condition. In order to enhance the productivity of late sown mustard, it is important to develop suitable nutrient management practices for mustard to boost its growth. Keeping in view the above facts, and to exploit the highest potential of the mustard under late sown condition, the present investigation was carried out to study the effect of nutrient management practices on seed yield of Indian mustard (*Brassica juncea* L.)" under late sown condition and its effect on soil health.

MATERIALS AND METHODS

The field experiment was conducted at the Crop Research Centre of the G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. The experimental soil contains 0.89% soil organic carbon, 224 kg/ha available N, 12.2 kg/ha available P and 309 kg/ha available K. The field experiment was laid out in randomized block design (RBD) with three replications. Each replication comprised of sixteen treatment combinations *viz.,* T_1-Control, T_2-RDF 50%, T3-RDF 75%, T_4-RDF 100%, T_5-RDF 50% + FYM 10 t/ha, T_6-RDF 50% + VC 5 t/ha, T_7-RDF 50% + FYM 5 t/ha + VC 2.5 t/ha, T_8-RDF 50%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*, T_9-RDF 75% + FYM 10 t/ha, T_{10}-RDF 75% + VC 5 t/ha, T_{11}-RDF 75% + FYM 5 t/ha + VC 2.5 t/ha, T_{12}-RDF 75% + FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*, T_{13}- RDF 100% + FYM 10 t/ha, T_{14}-RDF 100% + VC 5 t/ha, T_{15}-RDF 100% + FYM 5 t/ha + VC 2.5 t/ha, T_{16}-RDF 100% + FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*. Full amount of P_2O_5 and K_2O, along with 50% of nitrogen as per the treatment was applied as basal and remaining 50% of N was top dressed after first irrigation. *Azotobacter* culture was used at 10 g/kg seed. Mustard cv. 'Kranti' was grown during November-April, sown at a spacing of 30 × 15 cm.

The required quantity of organic manures *viz.* farmyard manure (FYM) and vermicompost (VC) as per the treatments was applied in the field ten days before sowing of both the crops on dry weight basis. The N, P and K concentration in organic manures was 1.4, 0.50 and 1.44% in VC, 0.47, 0.26, and 0.48% in FYM, respectively. All the standard agronomic practices were followed as per the schedule. Crop was harvested at maturity and the yield parameters were recorded. The composite soil samples were collected from each plot from 0 to 15 cm depth and analyzed for soil organic carbon (SCO) (Jackson, 1973) as well as available nitrogen (Subbiah and Asija 1956), available phosphorus (Olsen et al., 1954), available potassium (Hanway and Heidel, 1952). The microbial biomass carbon was estimated by chloroform fumigation and incubation method (CFIM) (Jenkinson, 1988) and dehydrogenase activity by colorimetric method (Casida et al., 1964). Seed and straw samples of crop were collected, digested and analyzed for N, P and K.

RESULTS AND DISCUSSION

Effect of INM modules on growth parameters

The number of branches/plant was significantly affected by integrated nutrient management (INM) modules. Among the different type of branches, the secondary branches were considerably higher than the primary and tertiary branches (Table 1). The highest number of total branches/plant were recorded with the application of 100% recommended dose of fertilizers (RDF) + FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter* was significantly higher than all other treatments. Application of 50% RDF or 75% RDF or 100% RDF with integration of FYM 10 t/ha, VC 5 t/ha and FYM 5 t/ha + VC 2.5 t/ha with or without *Azotobacter* resulted in higher number of total branches than application of chemical fertilizer alone; however,

Table 1. Number of different branches at harvest as influenced by different INM modules (pooled mean of two years).

Treatment		Number of branches at harvest				Number of siliqua/branch				Total no. of siliquae/plant
		Primary	Secondary	Tertiary	Total	Main	Primary	Secondary	Tertiary	
T_1	Control	4.5	9.5	1.5	15.5	27	94	67	5	193
T_2	RDF 50%	4.8	9.8	1.8	16.5	28	96	69	5	198
T_3	RDF 75%	4.8	9.8	1.8	16.5	29	98	70	5	202
T_4	RDF 100%	4.8	10.0	1.8	16.7	30	100	71	6	207
T_5	RDF 50% + FYM 10 t/ha	5.2	10.0	2.2	17.3	30	102	72	5	209
T_6	RDF 50% + VC 5 t/ha	5.2	10.0	2.2	17.3	31	103	72	5	211
T_7	RDF 50% + FYM 5 t/ha + VC 2.5 t/ha	5.2	10.3	2.2	17.7	32	104	74	6	216
T_8	RDF 50%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*	5.5	10.5	2.5	18.5	33	106	75	6	220
T_9	RDF 75% + FYM 10 t/ha	5.2	10.2	2.2	17.5	33	108	75	5	221
T_{10}	RDF 75% + VC 5 t/ha	5.3	10.2	2.5	17.8	34	110	76	5	225
T_{11}	RDF 75% + FYM 5 t/ha + VC 2.5 t/ha	5.5	10.8	2.5	18.8	35	111	77	6	229
T_{12}	RDF 75%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*	5.5	11.2	2.5	19.2	36	112	78	6	232
T_{13}	RDF 100% + FYM 10 t/ha	5.3	10.8	2.3	18.5	35	112	78	6	231
T_{14}	RDF 100% + VC 5 t/ha	5.5	11.0	2.5	19.0	36	113	79	7	235
T_{15}	RDF 100% + FYM 5 t/ha + VC 2.5 t/ha	5.7	11.7	2.8	20.3	36	114	80	7	237
T_{16}	RDF 100%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*	6.3	12.2	3.3	21.8	37	115	81	7	240
	S.Em.±	0.14	0.22	0.14	0.47	1	3	2	0.2	5
	C.D. at 5%	0.41	0.63	0.38	1.33	4	9	5	0.5	14

RDF = Recommended dose of fertilizers (120 kg N : 40 kg P_2O_5 : 20 kg K_2O); FYM = farmyard manure; VC = vermicompost.

alone; however, integration of VC proved to be slightly superior over FYM. These results are in close conformity with those of Singh and Kumar (1999) and Prasad (2000). The normal effect of nutrient on growth is to increase the height and vigour of the crop that results in increase in branching and total dry matter production (Holmes, 1980).

Effect of INM modules on yield and yield attributes

The highest number of siliqua/branch was observed on primary branch followed by secondary branch. The highest number of siliqua/branch was recorded with the integration of 100% recommended dose of fertilizers (RDF) + FYM 5 t/ha + vermicompost (VC) 2.5 t/ha + *Azotobacter,* which was significantly higher than the control, chemical fertilizers alone, integration of FYM or/and VC with 50% RDF and integration of FYM or VC with 75% RDF (Table 1). Number of seeds seeds/siliqua of Indian mustard was recorded highest on the main branch than primary, secondary and tertiary branches. The highest mean seeds/siliquae was observed in response to the application of 100% recommended dose of fertilizers (RDF) + FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter* which was significantly higher than all the treatments except 100% RDF + VC 5 t/ha and 100% RDF + FYM 5 t/ha + VC 2.5 t/ha (Table 2). This indicates that supplementing the 100% inorganic fertilizers with organic sources like FYM, VC and seed treatment with *Azotobacter* improve physical, chemical and biological properties of soil and also increase the crop yield and yield attributes. The positive response of application of FYM, VC and *Azotobacter* has also been reported by Mir et al.

Table 2. Seeds/siliqua (branch wise) as influenced by different INM modules (pooled mean of two years).

Treatment		Seeds/siliqua					Yield contribution of different branches (%)			
		Main	Primary	Secondary	Tertiary	Mean	Main	Primary	Secondary	Tertiary
T_1	Control	18.5	14.9	13.5	5.0	13.0	3.32	40.66	55.81	0.22
T_2	RDF 50%	18.8	15.2	13.9	5.3	13.3	3.15	41.32	55.28	0.25
T_3	RDF 75%	18.9	15.6	14.3	5.6	13.6	3.14	41.38	55.18	0.31
T_4	RDF 100%	19.1	15.9	14.6	6.1	13.9	3.06	41.01	55.60	0.32
T_5	RDF 50% + FYM 10 t/ha	19.2	16.1	14.8	6.3	14.1	2.98	42.64	54.07	0.31
T_6	RDF 50% + VC 5 t/ha	19.2	16.3	15.0	6.5	14.3	2.95	42.91	53.76	0.38
T_7	RDF 50% + FYM 5 t/ha + VC 2.5 t/ha	19.4	16.5	15.4	6.7	14.5	2.92	41.76	54.94	0.38
T_8	RDF 50%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*	19.5	16.6	15.6	7.0	14.7	2.80	42.54	54.23	0.42
T_9	RDF 75% + FYM 10 t/ha	19.3	16.3	15.9	7.2	14.7	2.90	41.40	55.30	0.40
T_{10}	RDF 75% + VC 5 t/ha	19.7	16.7	16.1	7.3	15.0	2.88	42.42	54.26	0.44
T_{11}	RDF 75% + FYM 5 t/ha + VC 2.5 t/ha	19.8	16.9	16.3	7.5	15.1	2.83	41.71	55.04	0.42
T_{12}	RDF 75%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*	20.0	17.1	16.6	8.0	15.4	2.75	40.52	56.26	0.47
T_{13}	RDF 100% + FYM 10 t/ha	19.9	17.2	16.9	7.8	15.5	2.79	40.68	56.14	0.40
T_{14}	RDF 100% + VC 5 t/ha	20.1	17.4	17.1	8.5	15.8	2.71	40.85	55.92	0.53
T_{15}	RDF 100% + FYM 5 t/ha + VC 2.5 t/ha	20.4	17.4	17.3	8.9	16.0	2.66	39.78	56.98	0.58
T_{16}	RDF 100%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*	20.5	17.8	17.5	9.5	16.3	2.44	41.78	55.12	0.66
	S.Em.±	0.46	0.43	0.38	0.22	0.19				
	C.D. at 5%	1.31	1.23	1.08	0.63	0.54			-	

RDF = Recommended dose of fertilizers (120 kg N : 40 kg P_2O_5 : 20 kg K_2O); FYM = farmyard manure; VC = vermicompost.

(2003) and Premi et al. (2004). Among the different branches, the highest contribution was recorded from the secondary branches followed by primary branches (Table 2). Siliqua length and 1000 seed weight were also affected significantly due to different nutrient management practices. The integrated use of organic and inorganic sources of nutrients resulted in higher siliqua length and 1000- seed weight as compared the use of chemical fertilizer. All the nutrient management treatments (chemical fertilizer alone and integrated nutrient management treatments) resulted in significantly higher yield than the control. The highest seed yield was recorded with 100% recommended dose of fertilizers (RDF) + FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*, which was significantly higher than all the treatments except 100% RDF + FYM 5 t/ha + VC 2.5 t/ha (Table 3). Application of 100% RDF + FYM 5 t/ha + VC + *Azoto*bacter recorded 10.6 and 23.2% yield over 75 and 50% RDF along with FYM 5 t/ha + VC + *Azoto*bacter, respectively. The positive yield of mustard was also reported by Mir et al. (2003), Premi et al. (2004), Gudadhe et al. (2005) and Singh and Sinsinwar (2006) with different combinations of supplementary nutrients applied.

Effect of INM modules on oil content

In general, oil content decreased with increase in fertilizer levels while further increase was response of supplementary ingredients on seed recorded with addition of organic sources of nutrient supply. The highest oil content was recorded from seeds obtained from main branch followed by primary branch. The differences in oil content due to plant nutrient management practices were non-significant (Table 3). The highest seed oil content in mustard was recorded in control or no fertilization; however, the seed oil

Table 3. Length of siliqua, 1000 seed weight, seed yield and harvest index as influenced by different INM modules (pooled mean of two years).

Treatment		Length of siliqua (cm)	1000-seed weight (g)	Seed yield (q/ha)	Harvest index (%)	Oil content in seeds of different branches (%)				Mean oil content (%)
						Main	Primary	Secondary	Tertiary	
T_1	Control	3.4	3.60	5.30	20.62	41.7	40.7	40.7	35.6	39.7
T_2	RDF 50%	3.5	3.62	6.96	21.23	41.5	40.6	40.6	35.5	39.5
T_3	RDF 75%	3.6	3.63	8.22	20.16	40.5	39.8	39.4	34.3	38.5
T_4	RDF 100%	3.7	3.63	8.99	20.11	40.5	39.6	39.4	34.1	38.4
T_5	RDF 50% + FYM 10 t/ha	3.7	3.64	8.92	20.18	41.6	40.7	40.7	35.6	39.6
T_6	RDF 50% + VC 5 t/ha	3.7	3.65	9.36	20.59	41.5	40.7	40.7	35.6	39.6
T_7	RDF 50% + FYM 5 t/ha + VC 2.5 t/ha	3.8	3.66	10.01	21.07	40.7	39.9	39.8	34.8	38.8
T_8	RDF 50%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*	3.9	3.68	11.09	22.79	40.7	40.0	39.9	35.0	38.9
T_9	RDF 75% + FYM 10 t/ha	3.9	3.68	10.61	21.11	41.2	40.4	40.3	35.4	39.3
T_{10}	RDF 75% + VC 5 t/ha	3.9	3.70	10.93	22.11	41.2	40.5	40.4	35.6	39.4
T_{11}	RDF 75% + FYM 5 t/ha + VC 2.5 t/ha	4.1	3.74	11.82	22.08	40.8	40.2	39.9	35.3	39.0
T_{12}	RDF 75%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*	4.1	3.76	12.34	23.43	40.8	40.3	40.0	35.5	39.1
T_{13}	RDF 100% + FYM 10 t/ha	4.1	3.77	11.72	21.78	40.5	39.8	39.6	34.4	38.6
T_{14}	RDF 100% + VC 5 t/ha	4.2	3.80	12.23	22.39	40.2	39.8	39.3	34.8	38.5
T_{15}	RDF 100% + FYM 5 t/ha + VC 2.5 t/ha	4.2	3.83	13.13	23.19	40.5	39.7	39.4	34.4	38.5
T_{16}	RDF 100%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*	4.3	3.85	13.64	23.72	40.2	39.5	39.3	34.5	38.3
	S.Em.±	0.10	0.04	0.41	0.83	0.7	0.7	1.0	0.8	0.7
	C.D. at 5%	0.30	0.12	1.18	2.34	NS	NS	NS	NS	NS

RDF = Recommended dose of fertilizers (120 kg N : 40 kg P_2O_5 : 20 kg K_2O); FYM = farmyard manure; VC = vermicompost.

content significantly decreased with the recommended dose of fertilizer. This may be due to the fact that the availability of nitrogen increases the proportion of protein substances in the seed leaving a potential deficiency of carbohydrates to be degraded to acetyl Co-A for the synthesis of fatty acids (Prasad, 2000;Kandpal, 2001).

Effect of INM modules on nutrient uptake

The INM modules had significant effect on nutrient uptake by mustard (Table 4). The highest total nitrogen uptake was observed with 100% recommended dose of fertilizers (RDF) + FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*, which was statistically at par with 100% RDF + FYM 5 t/ha + VC 2.5 t/ha and 100% RDF + VC 5 t/ha. The highest total phosphorus uptake was also found with 100% recommended dose of fertilizers (RDF) + FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*, which was significantly higher than all the treatments except 100% RDF + FYM 5 t/ha + VC 2.5 t/ha, 100% RDF + VC 5 t/ha and 100% RDF + FYM 10 t/ha. Like N and P, the maximum potassium uptake was recorded with 100% RDF + FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*. The lowest N, P and K uptake was found in control. The total NPK uptake by late sown Indian mustard ranged from 76.1 kg/ha in the control to 187.2 kg/ha in 100% recommended dose of fertilizers (RDF) + FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*.

Effect of INM modules on soil quality parameters

The soil organic carbon (SOC) increased from the initial value with the application of FYM or/and VC along with chemical fertilizers (Table 5). The SOC decreased in response to the application of chemical

Table 4. Nutrient uptake of mustard as influenced by different INM modules (pooled mean of two years).

Treatment		Nutrient uptake (kg/ha)								
		Nitrogen			Phosphorus			Potassium		
		Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total
T_1	Control	17.80	9.20	27.00	3.85	6.65	10.50	5.20	33.40	38.60
T_2	RDF 50%	27.55	14.15	41.70	6.05	9.90	15.95	8.20	49.85	58.05
T_3	RDF 75%	27.65	15.35	43.00	6.05	10.65	16.70	8.20	53.70	61.90
T_4	RDF 100%	30.70	17.30	48.00	6.75	11.90	18.65	9.15	59.55	68.70
T_5	RDF 50% + FYM 10 t/ha	30.80	17.85	48.65	6.75	12.00	18.75	9.55	59.85	69.40
T_6	RDF 50% + VC 5 t/ha	31.90	17.80	49.70	6.95	11.95	18.90	9.45	59.55	69.00
T_7	RDF 50% + FYM 5 t/ha + VC 2.5 t/ha	34.20	18.90	53.10	7.45	12.50	19.95	10.15	62.05	72.20
T_8	RDF 50%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*	38.00	19.45	57.45	8.25	12.50	20.75	11.25	62.10	73.35
T_9	RDF 75% + FYM 10 t/ha	36.35	21.00	57.35	7.95	13.30	21.25	10.80	65.30	76.10
T_{10}	RDF 75% + VC 5 t/ha	37.55	20.95	58.50	8.20	13.05	21.25	11.15	64.30	75.45
T_{11}	RDF 75% + FYM 5 t/ha + VC 2.5 t/ha	40.95	22.95	63.90	8.85	14.05	22.90	12.10	69.30	81.40
T_{12}	RDF 75%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*	42.80	22.55	65.35	9.25	13.65	22.90	12.70	67.35	80.05
T_{13}	RDF 100% + FYM 10 t/ha	40.70	23.75	64.45	8.80	14.20	23.00	12.00	69.70	81.70
T_{14}	RDF 100% + VC 5 t/ha	42.70	24.40	67.10	9.25	14.35	23.60	12.55	70.70	83.25
T_{15}	RDF 100% + FYM 5 t/ha + VC 2.5 t/ha	46.10	25.15	71.25	9.95	14.80	24.75	13.60	73.10	86.70
T_{16}	RDF 100%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*	48.00	25.80	73.80	10.35	14.95	25.30	14.15	73.90	88.05
	S.Em.±	1.72	0.82	2.38	0.35	0.58	0.85	0.62	2.66	2.81
	C.D. at 5%	4.99	2.42	6.90	1.04	1.69	2.46	1.77	7.70	8.12

RDF = Recommended dose of fertilizers (120 kg N : 40 kg P_2O_5 : 20 kg K_2O); FYM = farmyard manure; VC = vermicompost.

fertilizer alone as well as control. The application of organic manure along with fertilizers adds carbon to soil (Sharma et al., 2009). The highest available nitrogen in soil was observed with the use of 100% RDF + VC 5 t/ha, which was significantly higher than the use of chemical fertilizer alone and the control.

The available soil N was increased with integration of organic and inorganic sources of nutrients as compared to recommended dose of fertilizers. While, available soil phosphorus also increased with the application of 75 or 100% RDF applied with FYM and/or VC. The highest available potassium in soil was recorded with the application of 100% RDF + VC 5 t/ha, which was significantly higher than the use of chemical fertilizer alone, 50% RDF + FYM 10 t/ha and control. It might be due to integration of chemical fertilizer with organic sources of nutrients (Raju and Reddy, 2000; Meena et al., 2015). The chemical fertilizers alone decreased microbial biomass carbon and dehydrogenise activity in soil as compared to the initial value; however, it increased response to INM modules. The highest microbial biomass carbon and dehydrogenase activity were recorded with 50% RDF + FYM 5 t/ha + VC 2.5 t/ha+ *Azotobacter*, which was significantly higher than chemical fertilizer (Table 5).

The lowest microbial biomass carbon and dehydrogenase activity were recorded in response to application of 100% RDF. The result is in close conformity with that of Meena et al.

Table 5. Soil properties as influenced by nutrient management practices at the end of experiment (pooled mean of two years).

Treatment		Organic carbon (%)	Available soil nutrients (kg/ha)			MBC (µg g^{-1} of soil)	DHA (µg TPF g^{-1} 24 hr^{-1})
			N	P	K		
T_1	Control	0.78	208.30	10.42	298.29	234.43	34.50
T_2	RDF 50%	0.84	213.80	10.19	291.43	232.23	33.53
T_3	RDF 75%	0.83	214.60	11.16	298.29	232.41	34.02
T_4	RDF 100%	0.84	219.16	11.62	301.56	229.76	33.64
T_5	RDF 50% + FYM 10 t/ha	0.97	225.24	11.84	305.53	283.31	42.71
T_6	RDF 50% + VC 5 t/ha	0.96	229.36	13.16	310.93	283.56	43.37
T_7	RDF 50% + FYM 5 t/ha + VC 2.5 t/ha	0.96	226.36	11.65	311.22	280.67	43.35
T_8	RDF 50%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*	0.96	228.24	13.41	309.55	295.15	46.93
T_9	RDF 75% + FYM 10 t/ha	0.96	232.76	13.90	315.29	276.31	41.94
T_{10}	RDF 75% + VC 5 t/ha	0.97	239.24	13.15	316.90	276.56	41.54
T_{11}	RDF 75% + FYM 5 t/ha + VC 2.5 t/ha	0.95	234.80	12.90	314.36	273.67	42.14
T_{12}	RDF 75%+ FYM 5 t/ha + VC 2.5 t/ha + *Azotobacter*	0.94	236.92	13.52	312.64	288.15	46.05
T_{13}	RDF 100% + FYM 10 t/ha	0.97	235.00	13.89	317.34	274.31	42.94
T_{14}	RDF 100% + VC 5 t/ha	0.95	241.76	14.28	319.15	274.56	41.87
T_{15}	RDF 100% + FYM 5 t/ha + VC 2.5 t/ha	0.96	237.76	14.05	317.84	271.67	42.48
T_{16}	RDF 100%+ FYM 5 t/ha + VC 2.5 t/ha +*Azotobacter*	0.97	238.00	14.07	315.56	286.13	45.73
	S.Em.±	0.03	6.02	0.36	4.23	8.82	2.04
	C.D. at 5%	0.10	17.38	1.05	12.22	25.48	5.88
Initial valves		0.89	224.00	12.20	309.00	235.33	34.27

RDF = Recommended dose of fertilizers (120 kg N : 40 kg P_2O_5 : 20 kg K_2O); FYM = farmyard manure; VC = vermicompost.

(2015). There is strong relationship between soil organic matter content and enzyme activities (Gracia et al., 1994). Addition of organic matter might have increased the biological activity of the soil (Min et al., 2003). These increases may be attributed to the increase of microbial processes, whereas the decrease in MBC and dehydrogenase activity by chemical fertilization may be due to poor physical conditions and lack of organic substrates in the soils (Kang et al., 2005). Hence, it is concluded that INM module provides higher number of branches/plant, siliqua/branch, seeds/siliquae and seed yield of Indian mustard besides improved soil organic carbon content, available N, P and K, microbial biomass carbon and dehydrogenise activity in the soil as compared to the application of 100% recommended dose of NPK.

Conclusion

The application of different integrated nutrient management (INM) modules significantly improved growth, yield attributes and soil quality parameters. Thus, based on a two years' study, it can be concluded that the application of chemical fertilizer in combination with organic manures and biofertilizers was the most suitable INM module/practice for the late sown Indian mustard in the Tarai belt of Uttarakhand.

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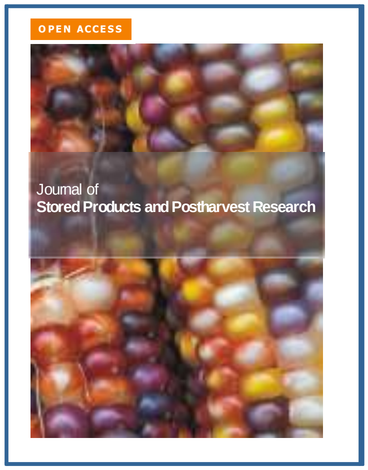
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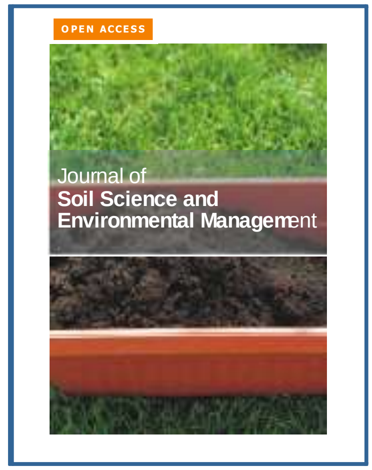
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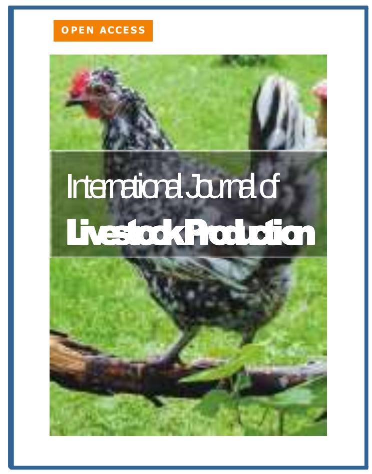
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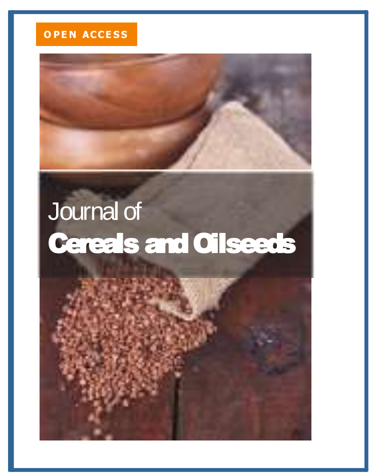
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