International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; SP6: 664-667

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(Special Issue -6)
3rd National Conference
On
PROMOTING & REINVIGORATING AGRI-HORTI, TECHNOLOGICAL INNOVATIONS [PRAGATI-2019]
(14-15 December, 2019)

Effect of integrated nutrient management on soil health and crop yield under rice-mustard cropping system in alluvial soil of Bihar, India

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Abstract
Integrated Nutrient Management (INM) approach is need of the hour which involves efficient and judicious use of all the major components of plant nutrient sources *viz.* chemical fertilizer in conjunction with manures and biofertilizers for sustaining soil fertility, health and productivity in intensive rice-mustard cropping systems. A field experiment was conducted in the Krishi Vigyan Kendra, Jamui, Bihar during 2014-15 and 2015-16 with rice (cv. Rajendra mahsoori-1) as *kharif* crop and mustard (cv. Pusa bold) as a *rabi* crop to investigate the influence of integrated nutrient management on soil health and yield of crops in rice-mustard cropping system. The experiment comprised of nine treatments, each replicated five times with a plot size of 20 m^2 in randomized block design. Soil samples were collected and analyzed for physical, chemical and biological properties before and after the crop harvest. Based on two years pooled data, the highest grain yield (q/ha) in rice and (q/ha) in mustard. The lowest grain yield was recorded in T_9 treatment. The treatments received organic amendments recorded higher microbial biomass carbon, basal soil respiration and fluorescein diacetate hydrolyzing activity over the treatments received chemical fertilizers in both rice and maize crop. So sound agronomic and environmentally acceptable integrated nutrient management practices are essential for sustaining higher yield and good soil health in rice – mustard cropping system in Bihar.

Keywords: Integrated nutrient management, microbial biomass, soil respiration, fluorescein diacetate hydrolyzing activity, Rice-mustard cropping system

Introduction
Rice-mustard is the most important cropping system after rice-wheat and rice-maize in Bihar. Mustard is major oilseed crop grown in about 0.9 lakh ha but its productivity (1350 kg/ha) while rice is major kharif crop grown in about 29.9 lakh ha with productivity (1919 kg/ha) in the state is much lower than its realizable yield potential (Anon. 2014) [1]. There is a great scope for increasing the production of rice and mustard by bringing more area under cultivation and increasing its productivity by applying organic manures (FYM) with balanced fertilization and maintaining soil fertility status. Indian soils are becoming deficient in N, P, K along with S due to intensive cultivation and use of high analysis fertilizers. In general cereal based cropping system, imbalance use of fertilizers and over-tilling that contribute a gradual reduction in organic matter (Gupta *et al*. 2003) [6]. Under such situation organic manures can be exploited to boost the soil health condition vis-à-vis production of crops and to improve fertilizer use efficiency. However, the use of total organic or inorganic nutrient sources has some limitations (Kandpal, 2001) [9]. Balanced combination of FYM, biofertilizers and chemical fertilizers facilitate profitable and sustainable production (Singh and Sinsinwar,

2006) [20]. On the other hand, continuous use of organics helps to build up soil humus and beneficial microbes besides improving the soil properties. Therefore, a substitution and/or supplementation of major nutrients with a considerable proportion from organic manures for sustaining higher yield, is of urgent necessity (De *et al.*, 2009) [4]. The integrated supply and use of plant nutrients from chemical fertilizer and organic manures has been found to produce higher crop yield than when each is applied alone (Randhawa, 1992) [14].
Studies in rice-mustard systems have indicated that combined inorganic and organic sources of nutrients are generally superior to the use of each component separately. With these considerations in mind, a field experiment was conducted in alluvial soil of southern east Bihar, India with objective to study the effect of integrated use of chemical fertilizers and organic sources on crop productivity and soil health in an irrigated rice-mustard system.

Material and Methods

A field experiment was conducted during 2014-15 and 2015-16 at the Experimental Farm of the Krishi Vigyan Kendra, Khadigram, Jamui, Bihar (24^{0}97' N and 88^{0}30' E). The soil was sandy loam in texture, bulk density (1.41 g/cc), and low water holding capacity (27.1%) with slightly acidic in soil reaction (pH 6.94) with non-saline conductivity (0.21 dSm^{-1}). The organic carbon content was 0.467% and the available nitrogen (N), available phosphorus (P), available potassium (K), microbial biomass carbon (MBC), basal soil respiration (BSR) and fluorescein diacetate hydrolyzing activity (FDHA) status in initial soils were 241.8 kg ha^{-1}, 9.6 kg ha^{-1},122.2 kg ha^{-1}, 204 µg g^{-1}, 0.82 µg CO_2–C g^{-1} soil h^{-1} at 25 °C soil and 20.0 µg fluorescein g^{-1} soil h^{-1} at 24 °C respectively.
Soil samples from top 15 cm depth were collected from the experimental site before sowing of maize crop (November, 2014) and also collected from each replication after harvest of crop. The soil samples were air dried, processed and passed through 2 mm sieve and properly stored in polythene bags for physico-chemical analysis. The field moist soil sample were collected in polythene bag, and kept in refrigerator for microbiological analysis. The physical property like bulk density was determined according to Singh (1980) [18] and water holding capacity was determined according to Piper (1950) [12]. The chemical properties like pH, organic carbon, available N, available P and available K were determined using standard methods of analysis. The biological properties like microbial biomass carbon (MBC) was determined according to Joergensen (1995) [8] and Vance *et al*. (1987) [22]. The basal soil respiration (BSR) was determined according to Alef (1995) [2, 8] and fluorescein diacetate hydrolyzing activity (FDHA) was determined according to Schnurer and Rosswall (1982) [17].

Treatment detail

The experiment was conducted during *rabi* of 2014-15 and 2015-16 with mustard as *rabi* crop and rice as a *kharif*, 2015 and 2016. The experiment plots of *rabi and kharif* season, comprised 9 treatments, each replicated five times with a plot size of 5.0 × 4.0 m^2 in randomized block design. The treatment details were as under:

Table 1: Treatment details of the experiment

Treatments	Mustard	Rice
T_1:	Farmers' practice (70:45:0 kg ha^{-1} N:P:K)	Farmers' practice (100:55:0 kg ha^{-1} N:P:K)
T_2:	T1 + Sulphur @ 20 kg ha^{-1}	T_1 + Vermicompost @ 2 t ha^{-1}
T_3:	T1 + Vermicompost @ 1 t ha^{-1}	T_1 + PSB @ 8 kg ha^{-1} (Soil application)
T_4:	T3 + Sulphur @ 20 kg ha^{-1}	T_2 + PSB @ 8 kg ha^{-1} (Soil application)
T_5:	100% NPK (80:40:40 kg ha^{-1})	100% NPK (100:40:20 kg ha^{-1})
T_6:	T5+ Sulphur @ 20 kg/ha	50% NPK + Vermicompost @ 2 t ha^{-1}
T_7:	50% NPK + Vermicompost @ 1 t ha^{-1}	T_5 + Vermicompost @ 2 t ha^{-1}
T_8:	T7 + Sulphur @ 20 kg ha^{-1}	T_7 + PSB @ 8 kg/ha (Soil application)
T_9:	Control	Control

After the field preparation, mustard (cv. Pusa bold) was sown at row spacing of 30 cm, using seed rate of 5 kg ha^{-1} on 27 November, 2014 and 29 November, 2015 respectively. After the harvest of wheat, plots were prepared for rice transplanting. 25 days old seedling of rice (cv. Rajendra mahsoori-1) was transplanted on 27 July, 2015 and 30 July, 2016 respectively in the plots with a spacing of 20 X 15 cm between row to row and plant to plant respectively.
Recommended package of practice were followed for crop cultivation during both the years. Yield and yield attribute data, namely, siliqua plant^{-1}, seed siliqua^{-1}, tiller hill^{-1}, panicle m^{-2}, 1000 grain weight and grain yield were recorded.
The experimental data pertaining to each character were subjected to statistical analysis by using the technique of analysis of variance (ANOVA) and the ANOVA was carried out by RBD using SPSS 16.0 statistical package. The mean values of the treatments were compared by DMRT at 5% probability level.

Results and Discussion

The crop yields and yield parameters of both the crops differed slightly during first and second year of the experiments, but the pattern of response to different nutrient management practices were similar in both the years. Hence, only pooled data of the two years are presented.

Table 2: Effect of different treatments on yield and yield parameters of mustard (Pooled data of two years i.e., 2014-15 and 2015-16)

Treatment	Number of Siliqua plant^{-1}	Number of Seed siliqua^{-1}	1000 grain weight (g)	Grain yield (q ha^{-1})
T_1	52.4^{h*}	10.4^{d}	2.27^{g}	13.70^{f}
T_2	61.9^{g}	10.5^{d}	2.76^{f}	14.75^{e}
T_3	67.4^{f}	12.5^{c}	2.89^{e}	15.90^{d}
T_4	71.2^{e}	13.0^{c}	3.03^{d}	16.50^{cd}
T_5	77.6^{d}	13.6^{c}	3.16^{c}	17.05^{bc}
T_6	83.5^{c}	14.8^{ab}	3.49^{b}	17.50^{b}
T_7	91.8^{b}	15.4^{a}	3.85^{a}	17.65^{b}
T_8	100.7^{a}	16.2^{a}	3.90^{a}	18.55^{a}
T_9	39.4^{i}	8.6^{e}	2.26^{g}	10.00^{g}

*Figures denoted by same alphabets are statically similar at 5% probability level by DMRT.

The yield components, *viz*., Number of siliqua plant^{-1}, number of seed siliqua^{-1}, and 1000-seed weight were significantly influenced due to integrated nutrient management treatments

(Table 2). The maximum number of siliquae per plant (100.7), number of seeds per siliqua (16.2) and 1000 seed weight (3.90 g) was noted with application of 100% NPK + vermicompost @ 1.0 t/ha + Sulphur @ 20 kg/ha (T8 treatment) and lowest in control (T9).Thus resulted in more translocation of nutrients through vermicompost towards sink development by Mandal and Singh (2004) [11]. The use of Vermicompost resulted in more translocation of nutrients toward sink development, consequently had more number of siliqua plant^{-1} and seed siliqua^{-1}has also been reported by Singh and Singh (2006) [19] and Kashved *et al.* (2010) [10]. Since the plant had larger vegetative growth on account of better root development and congenial moisture situations the seed size must have been increased due to more carbohydrates, synthesis process etc. under integrated nutrient supply by Mandal and Sinha (2004) [11] and Kashved *et al.* (2010) [10].

The maximum grain yield of mustard (18.55 q/ha) per hectare was recorded in T8 and minimum grain yield was recorded in T9 treatment (10.0 q/ha). The most probable reason for this phenomenon may be longer plant and increased dry matter, more vegetative growth under organic and inorganic nutrient supply. This might had resulted to increase straw yield, grain yield and consequently total biomass production by Tripathi *et al.* (2010) [21] and Premi *et al.* (2005) [13] reported similar result as yields.

Table 3: Effect of different treatments on yield and yield parameters of rice (Pooled data of two years i.e., 2015 and 2016)

Treatment	Number of tiller hill^{-1}	Number of panicle m^{-2}	1000 grain weight (g)	Grain yield (q ha^{-1})
T_1	23.0^{e*}	352.8^{g}	21.96^{e}	34.65^{g}
T_2	24.9^{cd}	370.4^{c}	22.80^{bcd}	44.05^{d}
T_3	24.8^{d}	359.1^{f}	22.40^{de}	38.40^{e}
T_4	25.8^{bc}	378.2^{b}	22.89^{bc}	44.95^{c}
T_5	24.8^{cd}	363.0^{e}	22.63^{cd}	40.95^{e}
T_6	25.0^{cd}	367.6^{d}	22.59^{cde}	43.95^{d}
T_7	26.5^{ab}	376.8^{b}	23.18^{ab}	46.50^{b}
T_8	27.0^{a}	387.1^{a}	23.57^{a}	48.65^{a}
T_9	21.7^{f}	350.4^{h}	21.53^{f}	28.25^{h}

*Figures denoted by same alphabets are statically similar at 5% probability level by DMRT.

A perusal of the data (Table 3) revealed that the integrated application of both organic and inorganic source of nutrient resulted in higher number of tiller hill^{-1}(27.0), number of panicle m^{-2}(387.1) and 1000 grain weight (23.57) with the T_8 treatment and lowest in T_9 treatment. The highest grain yield (48.65 q/ha) was recorded with the T_8 treatment and differ significantly with rest of treatments. The lowest grain yield (28.25 q/ha) was recorded in T_9 treatment. The higher grain yields of rice with integrated use of vermicompost, PSB and chemical fertilizers might be attributed to higher availability of macro and micro nutrients and facilitating uptake by plants resulting in better growth and dry matter production (Barik *et al.*, 2008) [3]. Improvement in yield due to combined application of inorganic fertilizer and vermicompost be attributed to control release of nutrients in the soil through mineralization of organic manure which might have facilitated better crop growth. Similar type of trends indicating beneficial effects of combination of vermicompost and inorganic fertilizers have also been reported by Jadhav *et al.* (1997) [7] and Rani and Shrivastava (1997) in rice [15].

Table 4: Organic carbon, MBC, BSR and FDHA in soil after harvest of mustard as influenced by different treatments (Pooled data of two years i.e., 2014-15 and 2015-16)

Treatment	O.C. (%)	MBC (µg g^{-1} soil)	BSR (µg CO_2-C g^{-1} soil h^{-1} at 25 °C)	FDHA(µg fluorescein g^{-1} soil h^{-1} at 24 °C)
T_1	0.452^{h*}	174.0^{h}	0.84^{g}	25.5^{f}
T_2	0.478^{e}	188.5^{f}	0.96^{e}	30.0^{d}
T_3	0.490^{c}	208.0^{d}	1.24^{c}	44.5^{a}
T_4	0.529^{a}	223.5^{a}	1.31^{b}	45.0^{a}
T_5	0.457^{g}	181.0^{g}	0.89^{f}	28.5^{e}
T_6	0.481^{d}	191.5^{e}	1.05^{d}	32.5^{c}
T_7	0.466^{f}	211.5^{c}	1.31^{b}	41.0^{b}
T_8	0.522^{b}	220.5^{b}	1.34^{a}	44.0^{a}
T_9	0.445^{i}	166.5^{i}	0.79^{h}	19.5^{g}

*Figures denoted by same alphabets are statically similar at 5% probability level by DMRT.

The data (Table 4) showed that the highest organic carbon (0.522%), MBC (220.5µg g^{-1} soil), BSR (1.34µg CO_2-C g^{-1}soil h^{-1} at 25 °C) and FDHA (44.0µg fluorescein g^{-1} soil h^{-1} at 24°C) were recorded in T_8 and all these differs significantly with rest of treatments. The lowest organic carbon (0.452%), MBC (166.5µg g^{-1} soil), BSR (0.79 µg CO_2–C g^{-1}soil h^{-1} at 25 °C) and FDHA (19.5 µg fluorescein g^{-1} soil h^{-1} at 24 °C) were recorded in T_9 treatment. Rao et al. (2010) found the positive result to increase the soil productivity with the help of integrated nutrient management.

Conclusion

Treatment T8, comprising 50% NPK+ Vermicompost @ 1 t/ha+ Sulphur @ 20 kg/ha (Soil application) in mustard and 100% NPK+ Vermicompost @ 2 t/ha+ PSB @ 8 kg/ha (Soil application) in rice, is the best application, suited for both the crops. So, we recommend it for higher productivity and maintenance of good soil health in rice-mustard cropping system in alluvial soil of Bihar.

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