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RESEARCH ARTICLE

Impact of nutrient management in rice-maize-greengram cropping system and integrated weed management treatments on summer greengram productivity

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ABSTRACT

Nutrient and weed management in crops and especially cropping system play an important role to enhance productivity and sustainability in different cropping systems. A field experiment was conducted for two consecutive years to evaluate the effect of nutrient management in preceding crops and integrated weed management practices in summer greengram on weeds growth and greengram productivity. The nutrients were applied in previous rice and maize crops and greengram was grown under residual soil fertility. The inorganic nitrogenous (N) fertilizer (25% of recommended dose) was substituted with bulky organic manures [farm yard manure (FYM) and vermicompost] and concentrated organic manures [Brassica seed meal (BSM) and neem cake]. The weed management treatments comprised of: herbicide use alone [post-emergence application (PoE) of imazethapyr 100 g/ha at 25 days after sowing (DAS)] and integrated weed management approach [pre-emergence application (PE) of pendimethalin 750 g/ha at 2 DAS followed by (*fb*) hoeing at 25 DAS]. The addition of concentrated organic manures (BSM and neem cake) effectively reduced the germination and overall growth of the weeds probably due to released allelochemicals. The N supplementation using neem cake and BSM decreased the weed biomass and reduced the nutrient uptake by weeds, and enhanced the nutrient uptake of greengram crop which ultimately enhanced the greengram growth and seed yield. This effect was more pronounced in the second year of study due to repeated application of organic manures. In comparison to use of herbicide alone (imazethapyr), the integrated weed management (pendimethalin PE *fb* hoeing) reduced the weed density and biomass accumulation by ~50 and 80%, respectively. The integrated weed management also enhanced the greengram seed yield by 12 and 9% compared to herbicide usage alone during 2015 and 2016, respectively.

Keywords: Brassica seed meal; Neem cake; Integrated weed management, Herbicide; Nutrient management, Rice-maize- greengram cropping system

INTRODUCTION

Rice-maize is one of the predominant cropping systems adopted in Indian subcontinent (Timsina *et al*. 2010). The productivity of this system and farmer's income are gradually declining due to enhancement in input cost. Repeated cultivation of high-input-driven crops resulted in the declination of factor productivity and soil health parameters. Inclusion of legume like greengram in this crop rotation could be a good choice to avoid such problems as greengram improves the soil fertility by fixing atmospheric nitrogen with root nodules and incorporation of greengram crop residue in succeeding rice crop was found more sustainable and profitable than traditional practice. Greengram is also a popular pulse preferred by the vegetarians of the country. It occupies around 304.8 thousand hectares with an annual production of about 134.5 thousand tons and productivity of 441 kg/ha in India (DES 2020).

The nutrients management is important for sustaining cropping system productivity but non-judicious use of synthetic fertilizers resulted in deterioration of soil health and other ecological parameters (Pingali 2012, Doran and Parkin 1994) which are amongst the key constrains for food production and security. The improvement of soil health parameters are needed for enhancing crop

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productivity. Integration of various sources of nutrients, especially organic, plays a major role in correcting soil health parameters and enhancing the system productivity (Das *et al.* 2014; Saha *et al.* 2018). The use of bulky organic manures like farmyard manure (FYM) and vermicompost as integrated approach in rice–maize system has been widely studied (Kumara *et al.* 2015), but use of concentrated organic manures, *viz*. Brassica seed meal (BSM) and neem cake as nutrient source and their weed suppressing ability in rice–maize–greengram cropping system has not been explored that much yet.

Weeds are the major biotic constraints competing for nutrient, water, light and space, causing substantial crop yield loss (Ghosh *et al.* 2016). The agronomic management practices, more specifically nutrient management, play a major role in weed diversity and its degree of yield loss (Ghosh *et al* 2017a, 2020a&b, Kumar *et al.* 2018). The herbicides-based weed management strategy widely accepted by the farmers due to ease of application. But sole dependency on herbicides may cause development of herbicide-resistant weeds along with contamination of herbicides in food chain and causing environmental hazards (Arias-Estévez *et al.* 2008, Magne *et al.* 2006). The integration of chemical and mechanical weed management strategies provide better weed control than chemical method alone (Ghosh *et al.* 2017b). Therefore, this study was undertaken to quantify the residual effect of nutrient (organic manures) and weed management practices on weed growth, nutrient uptake and yield of greengram in rice–maize–greengram cropping system.

MATERIALS AND METHODS

This study was conducted during summer 2015 and 2016 at farmers' field of Uttar Chandamari village, Muratipur, Nadia, West Bengal, India (88°27' E longitude and 22°59' N latitude). The climate of experimental site was humid and subtropical, with an average annual rainfall of 1400 mm and most of which precipitated from June to September. During the study period, the rainfall; mean maximum and minimum temperature and relative humidity; and sunshine hours were 149 mm; 39.8 and 18.9°C; 92 and 34% and 7.76 hr in 2015; and 213 mm; 41.7 and 21.8°C; 93 and 37% and 7.52 hr in 2016, respectively. The soil of the experimental site was Gangetic alluvium (*Entisol*), clay loam in texture with pH of 6.27, electrical conductivity (dSm^{-1}) of 0.19, and medium in organic carbon (0.52%), low in available N (215 kg N/ha), high in available P (36.3 kg/ha), and medium in available K (173 kg/ha).

The study was conducted in a factorial randomized block design having two factors: nutrient and weed management. The nutrient management practices include: inorganic fertilizers alone (100% nitrogen, phosphorus and potassium); integration of inorganic fertilizers (75% nitrogen) with bulky organic manures (FYM and vermicompost) and concentrated organic manures (BSM and neem cake) for 25% of recommended nitrogen in rice and maize; whereas recommended P and K were applied through inorganic fertilizers. The fertilizer and manures were applied in previous rice and maize crops and greengram was grown under residual soil fertility. The weed management practices were: weedy (unweeded), herbicide [imazethapyr 100 g/ha at 25 days after sowing (DAS) as post-emergence application (PoE)] and integrated [pendimethalin 750 g/ha as pre-emergence application (PE) at 2 DAS followed by (*fb*) hoeing at 25 DAS]. The recommended dose of fertilizer for rice and maize crops was 60-30-30 and 200-60-60 kg N-P-K /ha. The nutrients were applied using urea (46% N), single superphosphate (16% P), and muriate of potash (60% K). The N content in organic manures were 1.54 to 1.59, 0.59 to 0.66, 4.80 to 4.90 and 5.13 to 5.30% in vermicompost, FYM, BSM and neem cake, respectively. Knapsack sprayer (16 liters' capacity) with flat fan nozzles was used for herbicide application and the spray volume was 500 l/ha.

The greengram (cv. *PDM-139*) was sown on 25th and 23rd March of 2015 and 2016, respectively with row to row and plant to plant spacing of 30 and 5-7 cm, respectively. Seeding rate of greengram was 25 kg/ha. The plot size of each treatment was 7.2 × 3.0 m and was separated from adjacent plots by 1.0 m. For uniform germination irrigation was applied after sowing and subsequent one irrigation was given at flowering stage of the crop. The plant biometric observations and destructive sampling was taken from second and third rows either side of each plot and for yield determination middle eighteen rows were harvested manually on 2nd June and 31st May of 2015 and 2016, respectively. The preceding rainy *(Kharif)* season rice crop cv. *Satabdi* (IET 4786) was manually transplanted in puddled soil with 20 cm row-to-row and 15 cm plant-to-plant spacing and winter *(Rabi)* maize cv. *'P-3396'* was sown with 60 and 30 cm row to row and plant to plant spacing, respectively.

Biometric measurements and nutrient analysis

Data on weed density and biomass accumulation at 25 and 50 DAS was taken from two quadrats (60 cm × 60 cm) of each plot. Weeds were cut at ground level, counted and cleaned with water followed by sun and hot-air oven-dried at 65 °C for 72hr and weighed. Five greengram plants were selected from each plot and data on height along with branches per plant were taken. For greengram plant biomass, plants were cut at ground level from 50 cm row length of 2nd or 3rd rows of either side of plot then sun and hot-air oven-dried at 65°C for 72hr and weighed for determination of plant dry biomass accumulation. Punching core of known area was used for greengram leaf area index (LAI) calculation. The dry weight of greengram of known area was recorded and the area-weight relationship was calculated. The leaf area of each treatment was worked out using this relationship. The LAI was calculated as per the formula given by Watson (1953). The seed and stover yield of greengram was determined from net plot area (5.4 m × 2.0 m). The harvested seeds were threshed and weighted at 14% moisture level.

$$\text{LAI} = \frac{\text{Area of total number of leaves (cm}^2\text{)}}{\text{The ground area from where leaf samples were collected (cm}^2\text{)}}$$

The weed and greengram plant samples from each treatment were collected at 50 DAS and harvest, respectively, then oven-dried, and ground for analyzing total N, P and K. The sum of total N, P and K was reflected as nutrient uptake. Total N was estimated by the micro-Kjeldahl method and P and K were determined as per the method of Jackson (1973).

Statistical analysis

The actual weed density (X) data were transformed [$\sqrt{(X + 0.5)}$] due to high variance before statistical analysis. Data were subjected to analysis of variance, and the analysis was done using GenStat software.

RESULTS AND DISCUSSION

Weed growth

During the experimentation the weed flora in greengram crop were *Echinochloa colona* (L.) Link., *Oplismenus composites* (L.) P. Beauv., *Cyperus rotundus* L., *Caesulia axillaris* Roxb., *Phyllanthus virgatus* G. Forst., *Alternanthera philoxeroides* (Mart.) Griseb. and *Physalis minima* L. The weed density at early growth stages of greengram (25 DAS) varied significantly in 2015 with different nutrient sources applied in previous crops, but it was non-significant in 2016 (**Table 1**). The weed density at later crop growth stage (50 DAS) varied statistically in second year and it was non-significant in first year. Supplementation of nutrient through concentrated organic manures (BSM and neem cake) in the earlier rice and maize crops significantly reduced weed density at 25 DAS in 2015 and at 50 DAS in 2016 in comparison to inorganic fertilizer application alone or nutrient supplementation with bulky organic manures (vermicompost and FYM). The biomass accumulation by weeds differed statistically with sources of nutrient, except at 25 DAS in the first year. As compared to FYM, nutrient supplementation through BSM applied to previous crops decreased weed dry biomass in greengram by 27% at 25 DAS in the second year. Weed biomass accumulation at later growth stage of greengram was decreased with the application of different organic manures in 2015, and by BSM and neem cake in 2016. The addition of BSM and neem cake over years had a cumulative effect in suppressing the weed growth in the second year of study, compared to the bulky organic manures and inorganic fertilizer. The performance of BSM and neem cake in reducing the weed biomass was mainly due to the residual effect in restricting the growth of weeds due to the allelochemicals present in mustard and neem cake which had allelopathic effect on weed seed germination and growth (Abdulla and Kumar 2014, Marley *et al.* 2004).

In both the years, weed management treatments significantly reduced the weed density and biomass at different crop growth stages. The application of pendimethalin as PE lessened the weed density at 25 DAS by 70.4 and 61.2% in 2015 and 2016, respectively. As compared to the single herbicide application (imazethapyr PoE), integrated weed management practice with PE herbicide *fb* hoeing reduced the weed density at 50 DAS by 48 and 51% in 2015 and 2016, respectively; while corresponding reduction in weed biomass accumulation was 74 and 85% during two years. It could be due to the additional effect of hoeing in controlling those weeds that were not usually controlled by pendimethalin PE (Jinger *et al.* 2016). The weed density and biomass were reduced significantly in the second year of experimentation as compared to first year due to the puddling performed prior to rice transplanting.

Crop growth and yield

The plant growth parameters of greengram, *viz.* height, biomass, number of branches and leaf area index were measured at 40 DAS. The greengram plant height varied with the nutrient sources in both the years and dry matter accumulation only in second year of experimentation, whereas, number of branches/plant and leaf area index did not differ with the addition of organic manures in preceding rice and maize crops (**Table 2**). During first year of experimentation, highest plant height at 40 DAS (49.6 cm) was recorded in the plots receiving BSM as nutrient source. Addition of concentrated organic manures (BSM and neem cake) produced the tallest greengram plant in second year. The maximum biomass of greengram at 40 DAS was found with the use of neem cake as nutrient source in previous crops, which ultimately enhanced the plant growth and produced utmost greengram seed yield at harvest. The organic manures treatments improved residual effect compared to the sole inorganic fertilizer treatment. This may be due to the fact that the organic manure is a nutrient-rich, microbiologically-active amendment, releasing plant nutrients slowly but steadily to the crops in sequence, ultimately ensuing its superior performance in the succeeding crops (Xu *et al.* 2003, Srivastava *et al.* 2007).

Pendimethalin PE *fb* hoeing produced more robust greengram crop over sole PoE herbicide. The integrated weed management had not any added advantage over herbicide use alone in respect of number of branches/plant and leaf area index of greengram, yet it produced 12 and 9% higher greengram seed yield over sole imazethapyr PoE in 2015 and 2016, respectively. The integration of pendimethalin PE with hoeing at 25 DAS resulted in increased seed and stover yield of greengram by ~11 and 7% respectively, compared to imazethapyr PoE alone.

Table 1. Effect of different nutrient sources (residual) and weed management practices on weed growth in summer greengram

Treatment	Weed density (no./m^2)				Weed biomass (g/m^2)			
	25 DAS		50 DAS		25 DAS		50 DAS	
	2015	2016	2015	2016	2015	2016	2015	2016
Nutrient management								
100% RD_{NPK}	21.4 (459)	16.6 (274)	17.3 (298)	10.9 (118)	53.4	31.4	160.0	65.0
100% RD_{PK} +75% RD_N + 25% N (Vermicompost)	22.3 (499)	15.9 (254)	17.0 (288)	11.6 (134)	51.7	31.9	112.7	69.8
100% RD_{PK} +75% RD_N + 25% N (FYM)	22.5 (505)	16.7 (279)	17.6 (308)	11.3 (128)	56.2	36.5	128.8	63.5
100% RD_{PK} +75% RD_N + 25% N (BSM)	18.9 (358)	14.7 (215)	16.9 (284)	9.8 (96)	50.8	26.5	119.4	53.7
100% RD_{PK} +75% RD_N + 25% N (Neem cake)	20.0 (401)	15.1 (227)	16.2 (263)	9.8 (95)	51.8	30.1	110.1	49.3
LSD (p=0.05)	2.17	NS	NS	1.37	NS	7.35	12.60	10.35
Weed management								
Imazethapyr 100 g/ha PoE	24.7 (609)	17.4 (302)	16.2 (263)	10.1 (101)	63.0	38.0	89.8	45.3
Pendimethalin 750 g/ha PE *fb* hoeing	13.5 (182)	11.5 (132)	8.4 (70)	4.9 (23)	28.5	17.1	23.7	6.9
Un-weeded	25.0 (622)	18.5 (342)	26.3 (693)	17.1 (291)	66.7	38.8	265.1	128.5
LSD (p=0.05)	1.68	1.74	1.60	1.06	8.75	5.69	9.76	8.02

RD: Recommended dose through fertilizer; N: Nitrogen; P: Phosphorus; K: Potassium; FYM: Farm yard manure; BSM: Braseca seed meal; NS: Non significant; DAS: Days after sowing; PoE: Post-emergence application; PE: Pre-emergence; Values given in the parentheses were subjected to square root transformation before statistical analysis.

Table 2. Effect of different nutrient sources (residual) and weed management practices on plant growth at 40 DAS and seed yield of summer greengram

Treatment	Plant height (cm)		Dry weight (g/m^2)		No. of branches/ plant		Leaf area index		Seed yield (kg/ha)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Nutrient management										
100% RD_{NPK}	41.7	44.6	162	155	7.37	7.37	2.12	2.46	737	756
100% RD_{PK} +75% RD_N + 25% N (Vermicompost)	42.4	42.0	157	167	7.12	7.12	2.11	2.45	727	767
100% RD_{PK} +75% RD_N + 25% N (FYM)	43.8	44.7	164	177	7.38	7.38	2.14	2.35	735	804
100% RD_{PK} +75% RD_N + 25% N (BSM)	49.6	47.0	180	185	7.58	7.58	2.21	2.34	750	790
100% RD_{PK} +75% RD_N + 25% N (Neem cake)	43.8	47.3	172	169	7.66	7.66	2.20	2.38	752	813
LSD (p=0.05)	3.68	3.53	NS	25.4	NS	NS	NS	NS	NS	48.7
Weed management										
Imazethapyr 100 g/ha PoE	41.3	43.4	166	171	7.80	7.80	2.26	2.51	753	812
Pendimethalin 750 g/ha PE *fb* hoeing	43.6	44.4	188	189	7.82	7.82	2.29	2.55	845	884
Un-weeded	47.9	47.5	147	152	6.65	6.65	1.92	2.13	623	662
LSD (p=0.05)	2.85	2.73	19.0	19.7	0.49	0.49	0.29	0.33	38.6	37.8

RD: Recommended dose through fertilizer; N: Nitrogen; P: Phosphorus; K: Potassium; FYM: Farm yard manure; BSM: Braseca seed meal; *fb*: Followed by; NS: Non significant; DAS: Days after sowing; PoE: Post-emergence application; PE: Pre-emergence

Nutrient uptake by weed and crop

The nutrient supply through organic sources had significant impact on nutrient uptake by greengram seed and stover in 2016 and 2015, respectively; whereas nutrient harvest index was influenced in both the years of study (**Table 3**). The application of FYM and neem cake in previous crops enhanced the nutrient uptake of greengram seed and nutrient supplementation using vermicompost maximized the nutrient uptake of greengram stover. The higher nutrient harvest index was found with the plots receiving BSM and neem cake in 2015 and 2016, respectively for nutrient supplementation in previous rice and maize crops.

Herbicide usage and integrated weed management practices significantly reduced weed growth and eventually restricted the nutrient uptake by weeds and enhanced the nutrient uptake by greengram seed and stover. These observations are in conformity with the findings of Kataria *et al.* (2016) who also reported that integrated weed management practices like pendimethalin PE followed by imazethapyr + imazamox PoE at 30 DAS effectively reduced nutrient uptake by weeds in greengram crop.

Economics

The economics of greengram was varied with the variation in the residual impact of different nutrient management practices applied to the preceding crops as well as with the direct impact of different weed management practices used in greengram (**Table 4**). The total treatment cost in greengram has varied with the variation in the cost for

Table 3. Effect of different nutrient sources (residual) and weed management practices on nutrient uptake by weeds at 50 DAS and crop at harvest

Treatment	Nutrient uptake						Nutrient harvest index	
	Weeds (kg/ha)		Seed (kg/ha)		Stover (kg/ha)			
	2015	2016	2015	2016	2015	2016	2015	2016
Nutrient management								
100% RD_{NPK}	37.00	15.13	13.96	15.73	58.39	67.31	19.25	18.91
100% RD_{PK} +75% RD_N + 25% N (Vermicompost)	26.29	16.68	14.44	16.20	60.71	66.97	19.19	19.48
100% RD_{PK} +75% RD_N + 25% N (FYM)	29.82	14.90	14.80	17.12	55.42	67.79	20.97	20.13
100% RD_{PK} +75% RD_N + 25% N (BSM)	27.33	12.13	14.87	16.47	53.49	70.37	21.68	18.86
100% RD_{PK} +75% RD_N + 25% N (Neem cake)	25.20	11.04	14.94	17.02	58.20	64.96	20.65	20.73
LSD (p=0.05)	2.99	2.38	NS	1.01	4.08	NS	1.02	1.17
Weed management								
Imazethapyr 100 g/ha PoE	19.73	9.72	14.68	16.94	59.36	67.69	19.91	20.08
Pendimethalin 750 g/ha PE *fb* hoeing	5.49	1.53	16.85	18.72	62.75	73.15	21.24	20.41
Un-weeded	62.16	30.67	12.28	13.86	49.62	61.61	19.90	18.38
LSD (p=0.05)	2.32	1.85	0.74	0.78	3.16	3.69	0.79	0.91

RD: Recommended dose through fertilizer; N: Nitrogen; P: Phosphorus; K: Potassium; FYM: Farm yard manure; BSM: Braseca seed meal; *fb*: Followed by; NS: Non significant; DAS: Days after sowing; PoE: Post-emergence application; PE: Pre-emergence

Table 4. Economics for greengram production/hectare (based on mean data of two years)

Treatment combinations	Cultivation cost ($x10^3$ ₹)	Gross return ($x10^3$ ₹)	Net return ($x10^3$ ₹)	Benefit- cost ratio	Economic efficiency (₹/day/ha)
*NM_1×WM_1	32.48	35.21	2.72	1.08	39
×WM_2	34.72	43.62	8.90	1.26	129
×WM_3	39.49	47.05	7.56	1.19	110
NM_2×WM_1	32.48	36.14	3.65	1.11	53
×WM_2	34.72	43.80	9.08	1.26	132
×WM_3	39.49	46.19	6.69	1.17	97
NM_3×WM_1	32.48	36.23	3.74	1.12	54
×WM_2	34.72	44.19	9.47	1.27	137
×WM_3	39.49	49.06	9.56	1.24	139
NM_4×WM_1	32.48	36.27	3.79	1.12	55
×WM_2	34.72	42.60	7.88	1.23	114
×WM_3	39.49	50.86	11.37	1.29	165
NM_5×WM_1	32.48	37.27	4.79	1.15	69
×WM_2	34.72	45.21	10.49	1.30	152
×WM_3	39.49	48.90	9.41	1.24	136

*Residual; NM_1: 100% RD_{NPK}; NM_2: 100% RD_{PK} +75% RD_N + 25% N (vermicompost); NM_3: 100% RD_{PK} +75% RD_N + 25% N (FYM); NM_4: 100% RD_{PK} +75% RD_N + 25% N (BSM); NM_5: 100% RD_{PK} +75% RD_N + 25% N (neem cake); WM_1: Weedy; WM_2: Imazethapyr 100 g/ha at 25 DAS; WM_3: Pendimethalin 750 g/ha at 2 DAS followed by mechanical weeding at 25 DAS; FYM: Farm yard manure; BSM: Braseca seed meal; DAS: Days after sowing weed management practices only. With respect to sole herbicide use approach, the integrated approach required higher treatment cost. Due to the maximum production ability, the treatment superiority relating to gross return, net return, benefit-cost ratio as well as economic efficiency was realized in the plot previously treated with BSM under integrated approach in greengram.

Conclusions

Nutrient management in crops of a cropping system influences the growth and productivity of the component crops. The supplementation of organic nutrients (BSM and neem cake) has progressive residual impact on nutrient availability and growth of subsequent greengram crop and suppressed weed seed germination and growth. Integration of mechanical weeding (hoeing) with pendimethalin PE reduced the weed growth and enhanced the yield of greengram crop.

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