International Research Journal of Pure & Applied Chemistry

21(24): 358-371, 2020; Article no.IRJPAC.65902
ISSN: 2231-3443, NLM ID: 101647669

Impact of Integrated Nutrient Management on Performance of Oat-grasspea Cropping Systems, Competition Indices and Residual Soil Fertility

Saikat Biswas[1], Kalyan Jana[1,2*], Rajeev Kumar Agrawal[3] and Anandamoy Puste[1]

[1]Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal 741252, India.
[2]AICRP on Forage Crops and Utilization, Directorate of Research, Bidhan Chandra Krishi Viswavidyalaya, Kalyani- 741235, Nadia, West Bengal, India.
[3]ICAR-Indian Grassland and Fodder Research Institute (IGFRI), Division of Crop Production, Jhansi 284003, Uttar Pradesh, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author SB conducted the study, performed the laboratory and statistical analysis, wrote the protocol and manuscript. Author KJ designed the study and helped in final draft preparation. Author RKA proposed the study and made suitable advices for its execution. Authors KJ and AP provided necessary guidance as and when required during the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IRJPAC/2020/v21i2430378
Editor(s):
(1) Dr. Farzaneh Mohamadpour, University of Sistan and Baluchestan, Iran.
Reviewers:
(1) Caroline Salezzi Bonfá, Federal University of Jequitinhonha and Mucuri Valleys (UFVJM), Brazil.
(2) Rana Binyamin, University of Agriculture Faisalabad (UAF), Pakistan.
Complete Peer review History: http://www.sdiarticle4.com/review-history/65902

Original Research Article

Received 22 October 2020
Accepted 28 December 2020
Published 31 December 2020

ABSTRACT

A field experiment in 3 times replicated split plot design comprising 4 cropping systems (CS) (CS_1- Sole oat, CS_2- Sole grasspea, CS_3 and CS_4-oat-grasspea intercropping in 3:2 and 3:3 row ratios, respectively) in main plot and 3 integrated nutrient managements i.e. N_2, N_3 and N_4- 75% N through urea + rest N through FYM, vermi-compost and mustard oilcake, respectively along with N_1 – 100% RDF in sub plot, was carried out at Central Research Farm, B.C.K.V., India during winter season of 2015-16 and 2016-17. Pooled results expressed that highest yield of oat (15.40 q/ha) and grasspea (12.44 q/ha) were obtained from CS_4 and CS_2, respectively, under application of N_3. CS_4 exhibited

**Corresponding author: E-mail: kjanarrs@gmail.com;*

greater competition indices (LER: 1.16, RCC: 3.19, Aggressivity index: 0.184, CR: 1.39) and MAI (₹ 10,685.02) over CS_3 under application of N_3, showing 16% yield advantage as compared to sole cropping. Soil fertility remained best under CS_2 (OC: 0.53%, available N: 218.39 kg/ha, available P_2O_5: 49.59 kg/ha, available K_2O: 215.28 kg/ha) and among oat based CS, in CS_4 with N_3 application (OC: 0.52%, available N: 196.32 kg/ha, available P_2O_5: 44.28 kg/ha, available K_2O: 194.95 kg/ha).

Keywords: Grasspea; integrated nutrient management; intercropping; oat; yield.

1. INTRODUCTION

Food supply to burgeoning population is not only channelized from food crops but also from livestock sector which urges for improved forage productivity and supply. Livestock productivity in India is poor due to not only priority towards food crops cultivation but also poor nutritional quality of forage [1]. As there is limited scope of forage cultivation, time has come to utilize crops for dual purpose of livestock and human beings. Oat (*Avena sativa* L.) is one such dual purpose cereal crop grown in north western, central and eastern India [2] for its excellent growth habits, faster regrowth, high yield potential and ability to supply palatable, nutritious succulent green fodder to livestock. In India, human consumption of this non-traditional cereal is gaining popularity due to nutritional benefits. Grasspea (*Lathyrus sativus*) is a legume crop which is also gaining popularity now as intercrop or succeeding crop as it produces yield under limited resources and replenishes soil nitrogen depletion due to its ability to undergo biological nitrogen fixation (BNF) in roots through symbiosis with *Rhizobium leguminoseram*. In the present scenario of agricultural land shrinkage and climate bound risks, intercropping has become pertinent as it aims to effectively utilize available resources by simultaneous growing of crops together in distinctive manner at same land and time. It is hypothesized that cereal-legume intercropping is always found promising to provide greater production as well to improve soil fertility [3].

Today unsatisfactory crop yield is a major issue. With excessive use of NPK fertilizers and very scarce application of organic manure, the soil is now becoming deficient in various secondary and micro nutrients. In earlier days, the problem did not arise as only manures were used to supply nutrients and to improve soil fertility [4]. However, in order to meet country's current food demand, continuous cropping has to rely on chemical fertilizers, which altogether deplete soil fertility and leave environmental footprints. Still, there is no complete alternative of chemical fertilizers right now. In this regard, integrated nutrient management (INM) can be a boon to rejuvenate soil fertility and minimize environmental hazards. Improvement of crop growth above and below ground surface in oat-grasspea intercropping system under various INM options was previously reported by [5,6]. Improvement of quality and green forage yield of oat was also documented by [7] in oat-grasspea intercropping system under various INM options. Moreover, many other research works show that integrated use of organic and inorganic nutrient sources has already boosted yield of various crops under intercropping systems. Considering these facts, the present research was planned to confirm the benefits of cereal-legume intercropping and thereby, to evaluate best oat-grasspea intercropping system under various INM options in new alluvial zone of West Bengal, India.

2. MATERIALS AND METHODS

2.1 Experiment site and Field Condition

The field experiment was conducted at Central Research Farm, Gayeshpur, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal (23°N latitude, 89°E longitude and 9.75 m above mean sea level and medium land in topography), India during winter season of 2015-16 and 2016-17.The soil was sandy loam in texture, neutral in reaction (pH 6.75), medium in organic carbon (0.51%), available K_2O (198.4 kg/ha), high in available P_2O_5 (47.2 kg/ha) and low in available N (196.5 kg/ha).

2.1.1 Treatment details

The experiment was conducted in split plot design and replicated thrice. The experiment consisted 4 levels of cropping system in the main plot and 4 levels of nutrient management in the sub plot.

Cropping systems were sole oat (CS_1), sole grasspea (CS_2), intercropping of oat with grasspea in 3:2 row ratio (CS_3) and in 3:3 row ratio (CS_4).

Nutrient management options were 100% recommended dose of fertilizers (RDF) through urea (N_1), 75% N through urea and rest N through FYM (N_2) or vermi-compost (N_3) or mustard oilcake (N_4).

2.1.2 Cultivation details

The oat variety 'OS-6' was sown continuously at 25 cm inter row distance @100 kg/ha, 70 kg/ha and 57 kg/ha for CS_1, CS_3 and CS_4, respectively, On the other hand, grasspea variety 'Ratan (Bio L 212)' was sown also continuously at 20 cm inter row distance @ 50 kg/ha, 15 kg/ha and 20 kg/ha for CS_2, CS_3 and CS_4, respectively. Sowing was done in the last week of November in each year. Plot size was 4 m × 3 m. RDF (N: P_2O_5: K_2O) for sole oat as well as for intercropping systems @ 80:60:40 kg/ha and for sole grasspea @ 20:40:30 kg/ha were applied as per treatments. Full doses of P_2O_5 and K_2O through S.S.P and M.O.P. were applied as basal while, N was applied in 3 splits (50% at basal in form of urea (25%) and FYM/vermi-compost/mustard oilcake (25%), 25%each at 25 days after sowing (DAS) and 1 day after cutting of oat made at 60 DAS). Other agronomic practices were adopted as recommended for the region.

2.2 Observations and Analysis

Observations covered panicle length, panicle weight, grains/panicle, test weight and grain yield of oat, and pod length, pods/plant, seeds/pod, test weight and seed yield of grasspea, recorded at harvest (120 DAS). Whether particular crop combination proved to be advantageous or not, competitive functions viz. Land equivalent ratio (LER), Aggressivity index (A), Relative crowding coefficient (RCC), Competitive ratio (CR) and Monetary advantage index (MAI) were worked out using methods suggested by [8-12] respectively (Table 1).

The data on yield components and yields were analysed following the analysis of variance method [13] and comparison of treatment means was done through LSD at 5% significance level.

Soil pH and fertility status were estimated before and after the experiment. Methods prescribed by [14-18] were followed for estimation of soil pH, organic carbon, available nitrogen, available phosphorus and available potassium, respectively.

Table 1. Expression of various competition indices under intercropping system

$LER = LER_a + LER_b = (Y_{ab}/Y_{aa}) + (Y_{ba}/Y_{bb})$	Where, Y_{ab}= Intercrop yield of species 'a' in presence of species 'b' Y_{ba}= Intercrop yield of species 'b' in presence of species 'a' Y_{aa}= Pure stand yield of species 'a' Y_{bb} = Pure stand yield of species 'b' Z_{ab}= Sown proportion of species 'a' (intercropped with 'b') Z_{ba}= Sown proportion of species 'b' (intercropped with 'a') A_{ab} = Aggressivity of species 'a' in presence of species 'b' CR_a=Competitive ratio of species a in mixture with species b CR_b=Competitive ratio of species b in mixture with species a K_{ab}=Co-efficient of 'a' in presence of 'b' K_{ba}=Co-efficient of 'b' in presence of 'a'
Aggressivity $(A_{ab}) = [Y_{ab}/(Y_{aa} \times Z_{ab})] - [Y_{ba}/(Y_{bb} \times Z_{ba})]$	
$CR_a = (LER_a/LER_b) \times (Z_{ba}/Z_{ab})$ $CR_b = (LER_b/LER_a) \times (Z_{ab}/Z_{ba})$	
$K_{ab} = [Y_{ab}/(Y_{aa} - Y_{ab})] \times (Z_{ba}/Z_{ab})$ $K_{ba} = [Y_{ba}/(Y_{bb} - Y_{ba})] \times (Z_{ab}/Z_{ba})$ $RCC (K) = K_{ab} + K_{ba}$	
MAI = Value of combined intercrop yield × [(LER-1)/LER]	

3. RESULTS AND DISCUSSION

3.1 Yield Attributes and Yield of Oat

The pooled data (Table 2) depicted that oat-grasspea intercropping sytem and various nutrient management options exerted significant effects on yield attributes and yield of oat except panicle length and test weight. Among the three oat based cropping systems, highest panicle length (26.74 cm), panicle weight (2.98 g), grains/panicle (56.10) and test weight (37.80 g) were observed from 3:3 intercropping system (CS_4). On a contary, sole oat showed the lowest result. Grain yield also exhibited similar trend with best result obtained from CS_4 (13.44 q/ha) followed by CS_3 (12.36 q/ha). It might be due to the benefits of BNF of grasspea on component crop oat. The present result agreed the findings of [19] in maize-mungbean intercropping system. According to Senaratne et al*.* [20], cereal in association with legume in intercropping system can draw nitogen fixed biologically by legume crop. It might be also due to better utilization of light, space etc under intercropping system. Similar type of finding was repeorted earlier by [21] in maize-legume intercropping system as they observed maximum harvesting of solar radiation, proper utilization of land area under intercropping system, which finally improved the growth and productivity of component crops. The highest panicle length (26.73 cm), panicle weight (3.01 g), grains/panicle (56.94) and test weight (37.90 g) were observed in 75% N through urea + rest N through vermi-compost (N_3). Consequently, highest grain yield (13.40 q/ha) was obtained where N_3 was used. It could be attributed to the beneficial effect of vermi-compost on oat by stimulating soil microbial activities and continuously supplying various plant nutrients specially nitrogen to oat. Similar beneficial effect of vermi-compost was earlier reported by Cavender ND et at [22] in sorghum. Interaction effect had significant influence on panicle weight, grains/panicle and grain yield of oat. Highest panicle weight (3.25 g) (Fig 1), grains/panicle (62.30) (Fig 2) and grain yield (15.40 q/ha) (Fig 3) were experienced when N_3 was applied in CS_4 (CS_4N_3). On the other hand, CS_3N_1 expressed lowest panicle weight while, CS_1N_1 exhibited lowest grains/panicle and grain yield.

3.2 Yield Attributes and Yield of Grasspea

Pooled results (Table 2) revealed that except pods/plant and yield, rest characters were not significantly influenced by cropping system and nutrient management as those were variety specific. Sole crop (CS_2) attained maximum pod length (2.67 cm), pods/plant (40.58), seeds/pod (2.62), test weight (48.08 g) and seed yield (11.29 q/ha). It was next followed by CS_4. It might be due to greater plant population to undergo BNF, less disturbance and less inter-plant competition in sole grasspea. Kakon et al. [23] in maize-pea and Naik et al. [24] in maize-legumes intercropping systems noticed similar observations. Among intercropping systems, CS_4 outperformed CS_3 in terms of yield attributes and yield of grasspea. In both the intercropping systems although cereal crop oat got benefit from grasspea, there was no beneficial effect of cereal oat on grasspea crop. It thus, resulted in less yield of grasspea under intercropping systems. However, among two intercropping systems, yield attributes and seed yield of grasspea were comparatively more in 3:3 intercropping system of oat and grasspea (CS_4) due to availability of more space, light and also due to more biological N fixation and less shading effect from oat. Shading effect of maize hampering intercrop soybean was previously documented by [25]. Among the nutrient management options, highest pod length (2.67 cm), pods/plant (41.44), seeds/pod (2.61), test weight (48.03 g) and seed yield (11.22 q/ha) were observed when N_3 was used as integrated nutrient management option. The result was in close conformity with finding of [26] in cowpea. Vermi-compost, beside containing almost all macro and micronutrients, also acts as an excellent base for beneficial free living and symbiotic microbes. Vermi-compost improves soil aeration, root proliferation and makes water, nitrogen, phosphorus and several micronutrients available for crop growth. It thus, helps in better synthesis and translocation of carbohydrates in plant parts which reflects on their growth and productivity [27]. Bajracharya and Rai [28] working on chickpea reported that vermi-compost also helped in better nodulation in legume, facilitating plant's capability for BNF. It also provides quicker response than other ordinary composts. The present result might be due to the above facts regarding benefits of vermi-compost. Interaction effect was found to be significant in pods/plant and yield only. Among the combinations, CS_2N_3 and CS_3N_1 achieved respectively the highest and lowest pods/plant (Fig 4) and seed yield (Fig 5).

Table 2. Effect of cropping systems and nutrient management on yield attributes and yield of oat and grasspea (Pooled of 2 years)

Treatment	Oat								Grasspea						
	Panicle length (cm)	Panicle weight (g)		Number of grains per panicle		Test weight (g)	Grain yield (q/ha)*		Pod length (cm)	Number of pods per plant		Number of seeds per pod	Test weight (g)	Seed yield (q/ha)*	
Levels of cropping system (CS)															
CS_1	26.03	2.63		48.12		36.99	10.68		-	-		-	-	-	
CS_2	-	-		-		-	-		2.67	48.33		2.62	48.08	11.29	
CS_3	26.17	2.77		51.54		37.67	12.36		2.64	43.92		2.41	47.12	9.25	
CS_4	26.74	2.98		56.10		37.80	13.44		2.66	46.83		2.47	47.84	9.76	
S.Em (±)	0.21	0.05		0.14		0.46	0.12		0.01	0.31		0.06	0.25	0.17	
LSD (*p=0.05*)	NS	0.18		0.57		NS	0.48		NS	1.22		NS	NS	0.66	
Levels of nutrient management (N)															
N_1	25.99	2.54		45.78		36.99	11.20		2.65	38.22		2.44	47.37	9.09	
N_2	26.12	2.74		51.50		37.30	12.01		2.64	46.22		2.46	47.59	9.68	
N_3	26.73	3.01		56.94		37.90	13.40		2.67	51.33		2.61	48.03	11.22	
N_4	26.42	2.88		53.46		37.76	12.03		2.66	49.67		2.48	47.76	10.41	
S.Em (±)	0.32	0.07		0.50		1.199	0.11		0.01	0.32		0.06	0.24	0.11	
LSD(*p=0.05*)	NS	0.21		1.48		NS	0.31		NS	0.96		NS	NS	0.34	
Interaction	**-**	**CS×N**	**N×CS**	**CS×N**	**N ×CS**	**-**	**CS×N**	**N×CS**	**-**	**CS × N**	**N ×CS**	**-**	**-**	**CS×N**	**N×CS**
S.Em (±)	-	0.12	0.12	0.86	0.76	-	0.18	0.20	-	0.56	0.58	-	-	0.20	0.24
LSD (*p=0.05*)	-	0.37	0.37	2.56	2.28	-	0.55	0.67	-	1.67	1.87	-	-	0.58	0.83

**q/ha represented quintal/hectare (100 kg = 1 q)*

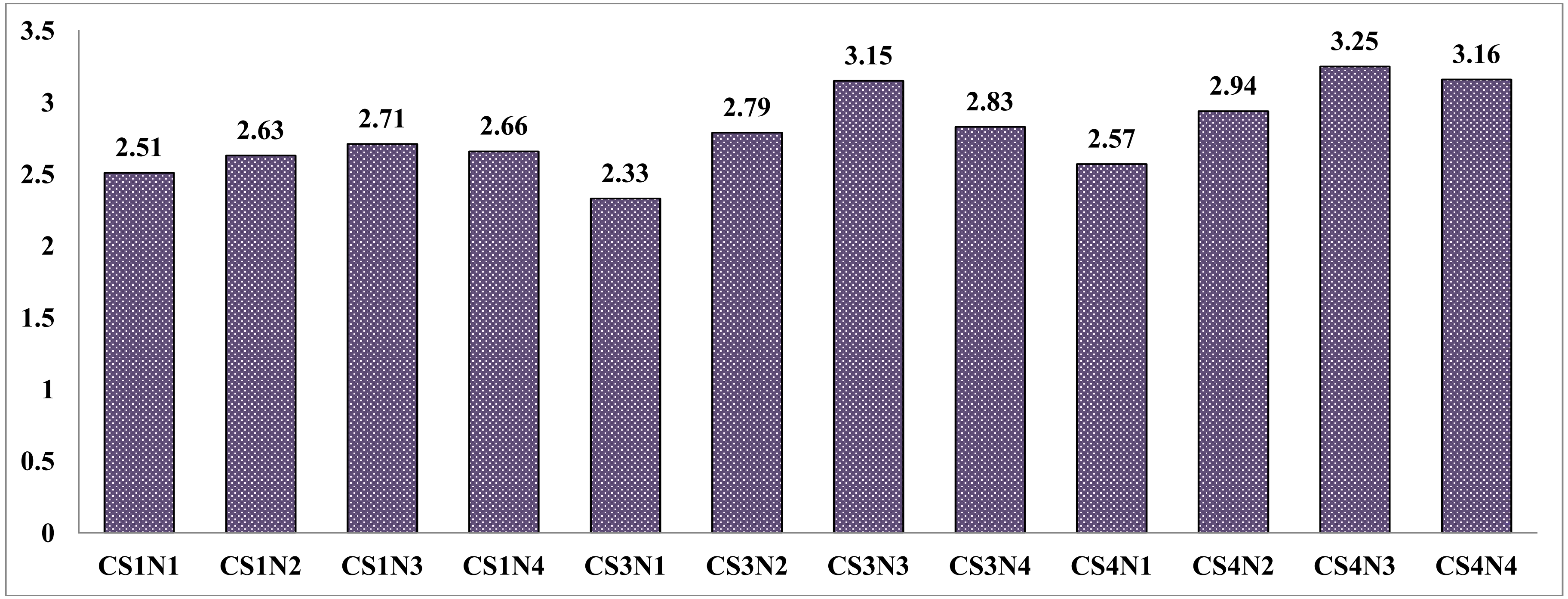

Fig. 1. Interaction effect of cropping system and nutrient management (CS ×N) on panicle weight of oat ($LSD_{0.05}$: 0.37)

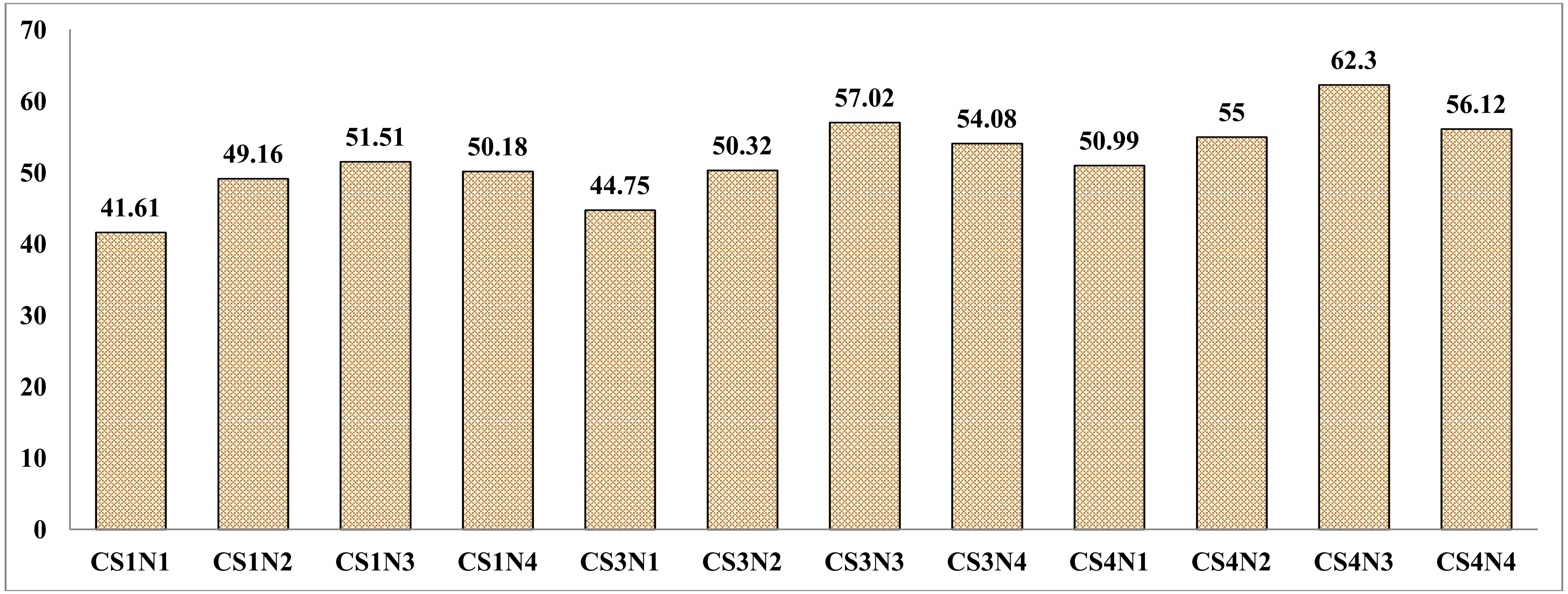

Fig. 2. Interaction effect of cropping system and nutrient management (CS ×N) on grains/panicle of oat (LSD$_{0.05}$: 2.56)

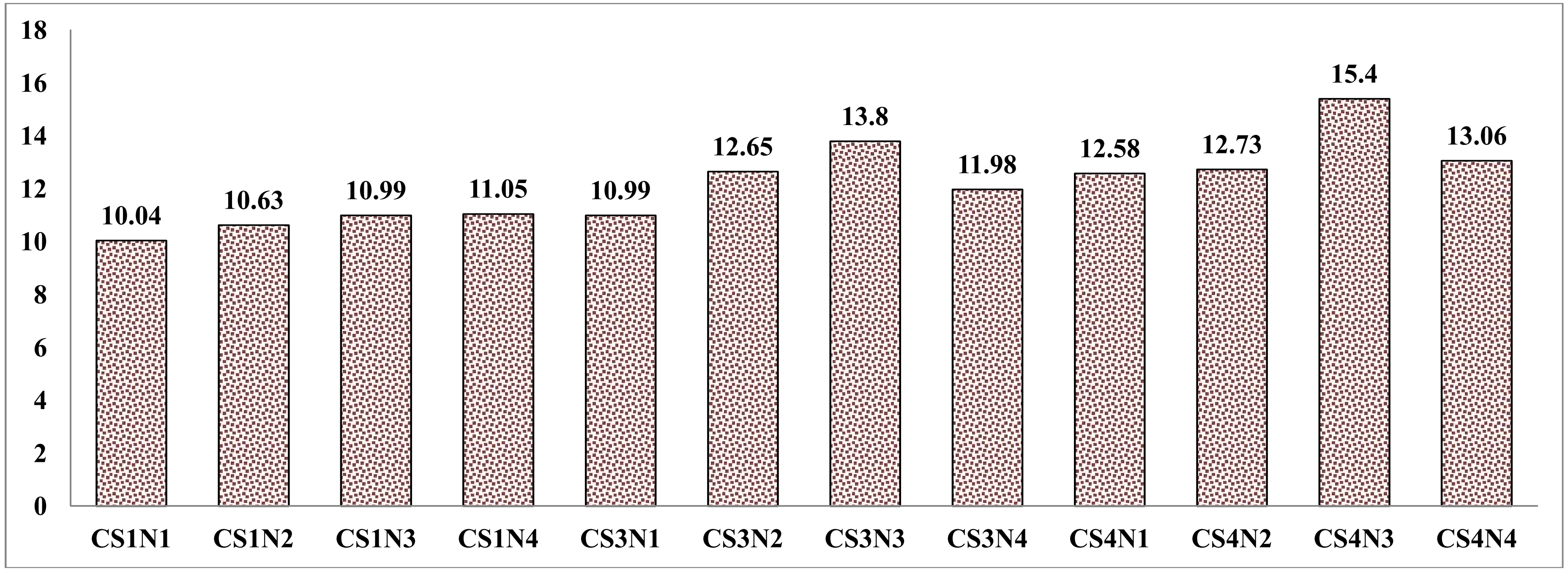

Fig 3. Interaction effect of cropping system and nutrient management (CS ×N) on grain yield of oat ($LSD_{0.05}$: 0.55)

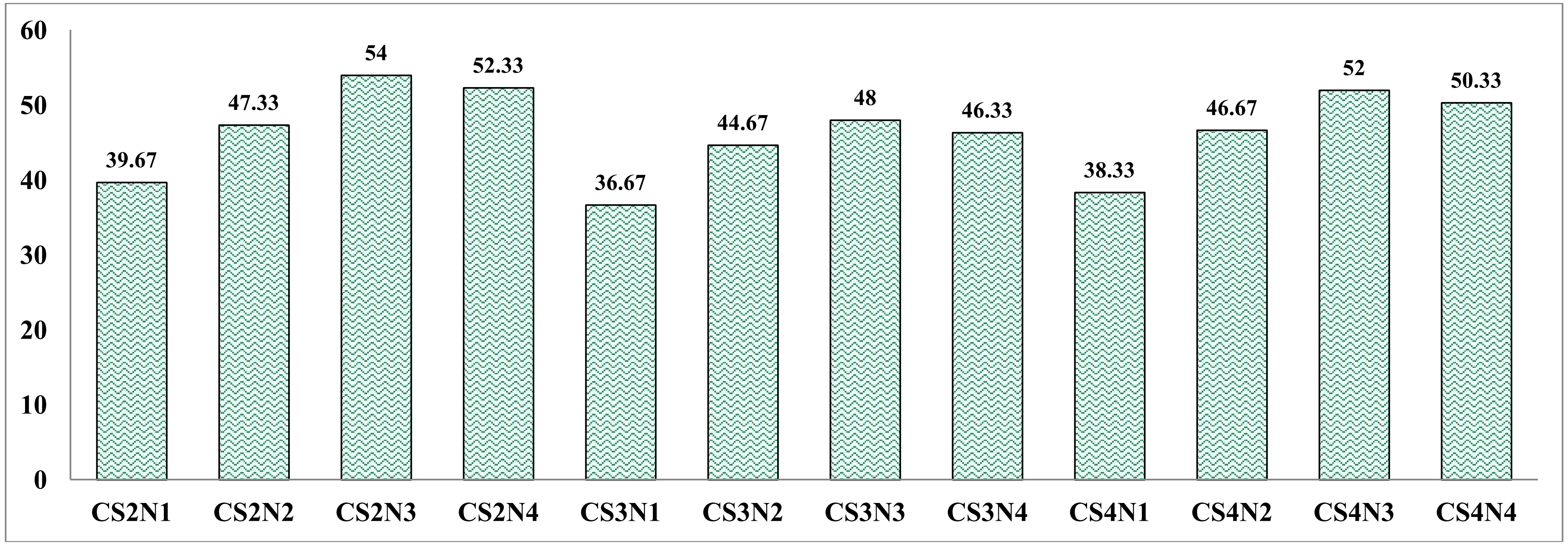

Fig. 4. Interaction effect of cropping system and nutrient management (CS ×N) on pods and plant of grasspea($LSD_{0.05}$: 1.67)

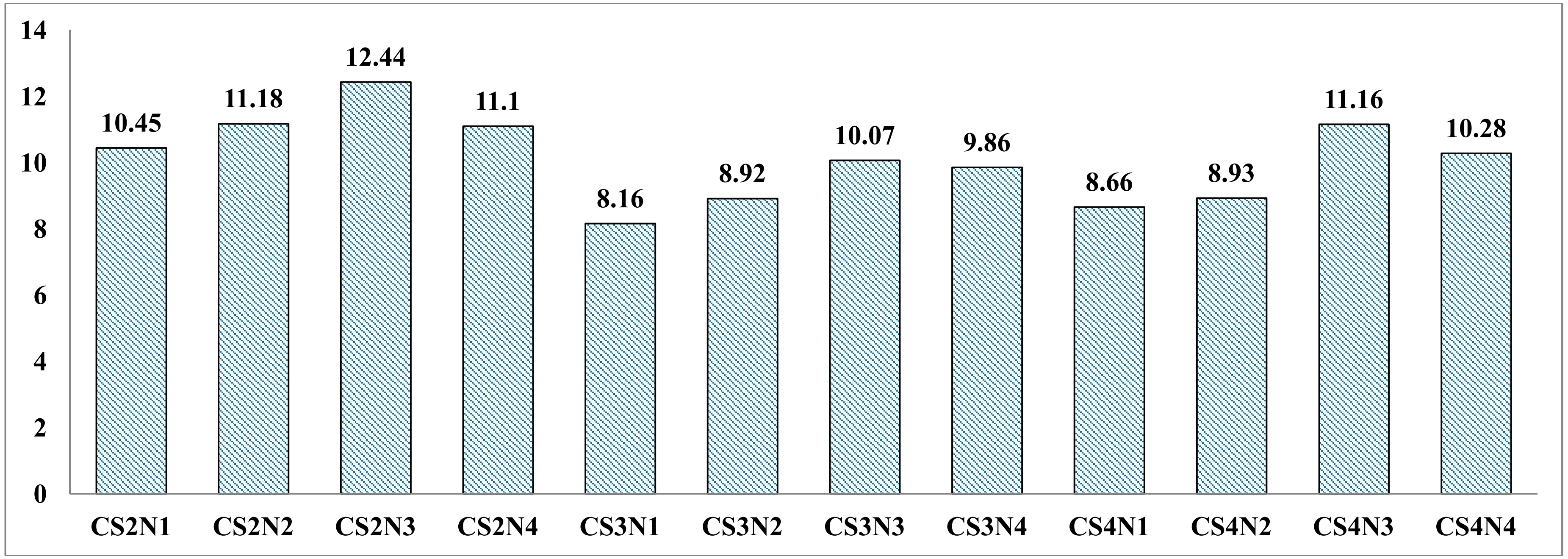

Fig. 5. Interaction effect of cropping system and nutrient management (CS ×N) on seed yield of grasspea($LSD_{0.05}$: 0.58)

3.3 Competition Indices and Monetary Advantage

Competition indices and MAI values were represented in Table 3. Biological efficiency of intercropping system over mono-cropping is clearly expressed by LER [29]. Among the two intercropping system (CS_3 and CS_4), combined LER was more in CS_4. It might be due to more plant population of grasspea in 3:3 intercropping system of oat and grasspea (CS_4) undergoing more amount of biological nitrogen fixation (BNF). It directly reflected on better yield of both the crops compared to other 3:2 intercropping system (CS_3). Better grasspea yield due to less shading effect and better utilization of available resources also contributed to greater LER in CS_4. Similar results were reported by [30] and [31] in maize-soybean and maize-cluster bean intercropping systems, respectively. Besides, beneficial effect of incorporating vermi-compost as organic nutrient source with inorganic fertilizers (N_3) on yield increase of both the component crops was also a major factor in elevating LER particularly in CS_4 (1.16) providing 16% yield advantage over sole cropping. RCC (>1.0) indicated advantages of both intercropping systems over sole cropping and greater advantage in CS_4 under application of N_3 (RCC: 3.19). The result corroborated the finding [32] in barley-grasspea intercropping system. Aggressivity index (A) gave an estimate of how much relative yield increase in one was greater than that of the other. Partial 'A' of oat and grasspea were positive and negative, respectively, in CS_4 indicating the dominance of oat over grasspea in that system. Oat showed more dominance under N_3 in CS_4 application (0.184). Accordingly, CR of oat was also found to be more in CS_4 than CS_3 inferring that oat was more competitive with grasspea in CS_4 specially, under N_3 application. Similar result was reported by [33] in maize-soybean intercropping. Chhetri and Sinha [34] also found almost similar observation regarding effect of integration of vermi-compost with fertilizer on competition indices in maize-cowpea intercropping. MAI reflected identical trend of competition indices expressing highest value (₹ 10685.02) obtained from CS_4 under N_3 application. Positive effects of legume in pearl millet-cowpea intercropping and INM in maize-soybean intercropping on MAI were earlier reported by Osman AN et al. [35] and Baghdadi A et al. [36] respectively.

3.4 Soil pH and Fertility Status

Soil pH after crop harvests ranged between 6.52 and 6.76 i.e. slightly acidic condition, which did not differ much from initial (6.75) inferring less or no influence of treatments (Table 4). However, slightly low pH was observed in CS_2 since legume acquired most nitrogen as N_2 from air than as NO_3 from soil [37]. Singh et al. [38] observed similar increase of soil acidity under cultivation of cowpea. It was also found that application of organics resulted in increase of soil acidity. Turning soil towards low pH occurred in the order of mustard oilcake>vermi-compost>FYM, irrespective of cropping systems. It might be due to accumulation of organic matter at the top soil which on decomposition released organic acids and thereby, incurred slightly decrease of soil pH [39]. OC % was decreased after harvesting due to the crop consumption in case of sole oat. It agreed the observation of [40]. However, cultivation of legume grasspea specially under sole cropping improved OC % slightly. It might be due to its greater carbon sequestration ability over cereal [40]. Available soil nitrogen (kg N/ha) was also found to be less than the initial value specially, in case of cereal oat. Improvement of post-harvest available N status

Table 3. Effect of nutrient management on competition indices under oat-grasspea intercropping systems (Pooled of 2 years)

Levels of nutrient management (N)	Combined LER		Relative crowding co-efficient (K)		Aggressivity index (A)		Competitive ratio (CR)		Monetary Advantage Index (MAI) (₹)	
	CS_3	CS_4	CS_3	CS_4	CS_3	CS_4	CS_3	CS_4	CS_3	CS_4
N_1	0.99	1.05	2.03	2.36	-0.116	0.151	0.77	1.34	-566.25	2941.32
N_2	1.04	1.01	2.25	2.13	-0.103	0.141	0.80	1.33	2399.20	624.46
N_3	1.07	1.16	2.43	3.19	-0.096	0.184	0.82	1.39	4448.24	10685.02
N_4	1.02	1.06	2.25	2.29	-0.190	0.066	0.67	1.14	1242.12	3869.59

Table 4. Effect of cropping systems and nutrient management on soil pH and fertility status (Pooled of 2 years)

Treatments		pH	OC (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
CS_1	N_1	6.76	0.45	130.67	32.24	136.45
	N_2	6.74	0.46	151.57	35.89	160.16
	N_3	6.69	0.49	160.72	38.07	165.95
	N_4	6.61	0.47	151.57	37.37	162.21
CS_2	N_1	6.70	0.49	197.25	47.31	184.67
	N_2	6.64	0.51	202.87	47.85	206.32
	N_3	6.63	0.53	218.39	49.59	215.28
	N_4	6.52	0.51	211.93	48.85	209.87
CS_3	N_1	6.74	0.47	171.57	35.37	157.71
	N_2	6.73	0.49	179.41	38.76	183.56
	N_3	6.63	0.51	192.28	41.15	192.11
	N_4	6.60	0.50	189.87	39.07	188.16
CS_4	N_1	6.68	0.48	179.41	37.15	163.09
	N_2	6.66	0.50	183.04	40.54	185.68
	N_3	6.62	0.52	196.32	44.28	194.95
	N_4	6.56	0.51	193.29	41.24	189.33
Initial		6.75	0.51	196.5	47.2	198.4

was however, achieved from CS_2 due to its high BNF capability [41]. CS_1 showed lowest N due to high consumption by cereal. Among intercropping systems, CS_4 had greater residual N due to more BNF than CS_3. Available phosphorus (kg P_2O_5/ha) and potassium (kg K_2O/ha) also showed similar trend of available N. Legume grasspea might mobilise phosphorus and potassium from deeper layer through root exudates and thereby, improved its availability at the surface [42,43]. Use of N_3 ensured better residual soil fertility as vermi-compost probably improved the soil nutrient content for a long time [44].

4. CONCLUSION

Overall, the study confirmed that cereal-legume intercropping system positively influenced crop performance. Based on the results, it can be concluded that 3:3 intercropping system of oat-grasspea using 75% inorganic N and 25% N from vermi-compost has performed best and therefore, it can be recommended to achieve higher grain and seed yield of oat and grasspea, respectively, greater yield advantage and soil fertility in new alluvial zone of West Bengal, India.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Roy D. Reap more biomass through diversity in forestry. Intensive Agriculture. 1993; XXXI(5-8): 23-26.
2. Raj MSP, Vyakaranahal BS. Effect of integrated nutrient and micronutrients treatment on plant growth parameters in oat cultivar (*Avena sativa* L.). International journal of plant sciences.2014;9(2):397-400.
3. Alvey S, Yang CM, Buerkert D, Crowley DE. Cereal/legume rotation effects on rhizosphere bacterial community structure in West African soils. Biology and Fertility of soils. 2003;37:73-82.
4. Sharpley AN, Mcdowell RW, Kleinman PJA. Amounts, forms and solubility of phosphorus in soils receiving manures. Soil Science Society of America. American Journal. 2004;68: 2048-2057.
5. Biswas S, Jana K, Khan R, Agrawal RK, Puste AM. Periodic dry matter accu-mulation and crop growth rate of oat and lathyrus as influenced by integrated nutrient management in intercropping systems. International Journal of Current Microbiology and Applied Sciences. 2019; 8(08): 2675-2686.
6. Biswas S, Jana K, Agrawal RK, Puste AM. Effect of integrated nutrient management on growth attributing characters of crops under various oat-lathyrus intercropping

system. The Pharma Innovation Journal. 2019;8(9):368-373.

7. Biswas S, Jana K, Agrawal RK, Puste AM. Effect of integrated nutrient management on green forage, dry matter and crude protein yield of oat in oat-Lathyrus intercropping system. Journal of Crop and Weed. 2020;16(2): 233-238.
8. Willey RW. Intercropping-its importance and research needs. Part I: Competition and yield advantage. Field Crops Abstracts. 1979;31(1):1-10.
9. McGilchrist CA. Analysis of competition experiments. Biometrics. 1965;21:975-985.
10. De Witt CT. On competition. Versiag Landbouw - Kundige Onderzoek. 1960; 66:1-28.
11. Willey RW, Rao MR. A competitive ratio for quantifying competition between intercrops. Experimental Agriculture. 1980; 16:117-125.
12. Ghosh PK. Growth, yield, competition and economics of groundnut/cereal fodder intercropping in the semi-arid tropics of India. Field Crops Research. 2004;88:227-237.
13. Panse VG, Sukhatme PV. Statistical methods for Agricultural workers. Indian Council of Agricultural research publication. New Delhi 1985; 87-89.
14. Jackson ML. Soil chemical analysis. Practice Hall of India Pvt. Ltd., New Delhi. 1967; 452-485.
15. Walkley A,Black IA. An examination of Degtjareff methods for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 1934; 37: 29-38.
16. Subbiah B, Asija GL. A rapid procedure for the estimation of available N in soils. Curr. Sci. 1956;25:259–260.
17. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S.D.A. Circular; 1954.
18. Brown AJ, Warncke D. Recommended chemical soil test procedures for the North Carolina Region, 499. In: Dahnke, W.C. (Ed.), North Dakota agricultural experimental station bulletin. 1988; 15–16.
19. Yadav AK, Chand S, Thenua OVS. Effect of integrated nutrient management on productivity of maize with mungbean intercropping. Global Journal of Bio-science and Biotechnology. 2016;5(1): 115-118.
20. Senaratne R, Liyanage NDL,Ratnasinghe DS. Effect of K on nitrogen fixation of intercrop groundnut and the competition between intercrop groundnut and maize. Fertility Research. 1993; 34:9-14.
21. Choudhary VK. Suitability of maize-legume intercrops with optimum row ratio in mid hills of Eastern Himalaya, India. SAARC Journal of Agriculture. 2014;12(2):52-62.
22. Cavender ND, Atiyeh RM, Michael K. Vermicompost stimulates mycorrhizal colonization of roots of *Sorghum bicolor* at the expence of plant growth. Pedobiologia. 2003;47:15-21.
23. Kakon SS, Saha RR, Ahmed F, Jahan MAHS. Maize-pea intercropping as influenced by planting system and row arrangement. Journal of Bangladesh Agricultural University. 2007; 5(1):37-41.
24. Naik MSP, Sumathi V, Kadiri L. Response of optimum nitrogen rate in maize with legume intercropping system. SAARC Journal of Agriculture. 2017;15(1):139-148.
25. Fan Y, Chen J, Cheng Y, Raza MA, Wu X, Wang Z, et al. Effect of shading and light recovery on the growth, leaf structure, and photosynthetic performance of soybean in a maize-soybean relay-strip intercropping system. PLoS ONE. 2018;13(5): e0198159.
26. Kumar A, Pandita VK. Effect of integrated nutrient management on seed yield and quality in cowpea. Legume Research. 2016;39(3):448-452.
27. Khan VM, Ahamad A, Yadav BL,Irfan M. Effect of vermicompost and biofertilizers on yield attributes and nutrient content and it's their uptake of cowpea (*Vigna unguiculata* (L.) Walp.). International Journal of Current Microbiology and Applied Sciences. 2017; 6(6):1045-1050.
28. Bajracharya SK,Rai SK. Study on effects of vermicompost on the nodulation and the yield of chickpea. Nepal Agricultural Research Journal. 2009;9:49-55.
29. Nedunchezhiyan M. Evaluation of sweet potato (*Ipomoea batatas*) based strip intercropping systems for yield, competition indices and nutrient uptake. Indian Journal of Agronomy. 2011;56(2): 98-103.
30. Habineza M, Kinama JM, Olubayo FM, Wanderi SW, Muthomi JW, Nzuve FM. Effect of intercropping maize and promiscuous soybean on growth and yield.

Journal of Experimental Agriculture International. 2017;18(6):1-21.

31. Patel JR, Rajagopal S. Production potential of forage maize (*Zea mays*) with legumes under intercropping system. Indian Journal of Agronomy. 2001;46:211-215.
32. Javanmard A, Shekari F, Dehghanian H. Evaluation of forage yield and competition indices for intercropped barley and legumes. International Journal of Agricultural and Biosystems Engineering. 2014; 8(2):193-196.
33. Cui L, Yang F, Wang X, Yong T, Liu X, Su B,Yang W. The competitive ability of intercropped soybean in two row ratios of maize-soybean relay strip intercropping. Asian Journal of Plant Science and Research. 2017; 7(3):1-10.
34. Chhetri B, Sinha AC. Effect of integrated nutrient management practices on maize (*Zea mays* L.) based intercropping system under Terai region of West Bengal. Advances in Research.2018;16(1):1-10.
35. Osman AN, Raebild A, Christiansen JL, Bayala J. Performance of cowpea (*Vigna unguiculata*) and pearl millet (*Pennisetum glaucum)* intercropped under *Parkia biglobosa* in an agroforestry system in Burkina Faso. African Journal of Agricultural Research. 2011;6(4):882-891.
36. Baghdadi A, Halim RA, Othman R, Yusof MM, Atashgahi ARM. Productivity, relative yield and plant growth of forage corn intercropped with soybean under different crop combination ratio. Legume Research. 2016;39(4):558-564.
37. Layek J, Das A, Mitran T, Nath C, Meena RS, Yadav GL, et al. Cereal+legume intercropping: An option for improving productivity and sustaining soil health. In: Legumes for soil health and sustainable management. Springer, Singapore. 2018; 347-386.
38. Singh KK, Ali M,Venkatesh MS. Pulses in cropping systems. IIPR, Kanpur. 2009;39.
39. Busari MA, Salako FK. Effect of tillage, poultry manure and NPK fertilizer on soil chemical properties and maize yield on an Alfisol at Abeokuta, south-western Nigeria. Nigerian Journal of Soil Science. 2013;23: 206–218.
40. Fox RH, Myers RJK,Vallis I. The nitrogen mineralization rate of legume residues in soil as influenced by their polyphenol, lignin and nitrogen contents. Plant Soil. 1990;129:251-259.
41. Yu Y, Xue L, Yang L. Winter legumes in rice crop rotations reduces nitrogen loss, and improves rice yield and soil nitrogen supply. Agron Sustain Dev. 2014;34:633–640.
42. Nuruzzaman M, Lambers H, Bolland MD, Veneklaas EJ. Phosphorus benefits of different legume crops to subsequent wheat grown in different soils of Western Australia. Plant Soil. 2005;271:175–187.
43. Sallaku G, Liko J, Rada Z, Balliu A. The effects of legume crops (pea and faba bean) on soil nutrients availability and yield parameters of subsequent cabbage crops under organic production conditions. Journal of Environmental Science and Engineering. 2016; A5: 619-625.
44. Dhakal Y, Meena RS,Kumar S. Effect of INM on nodulation, yield,quality and available nutrient status in soil after harvest of greengram. Legume Research. 2016; 39(4):590-594.

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