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SMART COVER CROP ROTATIONS: AGRONOMIC PARAMETERS AND NK EFFICIENCY INDICES OF RICE AS AFFECTED BY CROP ROTATIONS AND N APPLICATIONS RATES

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ABSTRACT

Continuous rice transplanting without crop rotation will reduce soil positive properties and crop productions in paddy field systems. Thus, the present study aimed to investigate the effect of cover crop rotations to enhance productivity and diminished chemical fertilizer application. The experiment was conducted as split plot based on a randomized complete blocks design with four replications in north of Iran, during 2015-16 and 2016-17. Six cover crop rotations including perko-rice, buko-rice, mixed cropping of clover + ramtil + phaselia-rice, clover-rice, faba bean-rice, and fallow-rice were used as main plots. Four levels of nitrogen fertilizer application included 0, 50, 100, and 150 kg.ha^{-1} of urea source as sub plots. The findings revealed that the maximum lodging index was achieved for perko-rice with 150 kg urea.ha^{-1}. Regarding the findings of yield components, the highest paddy yield (5147 kg.ha^{-1}) was achieved in perko-rice rotation with 100 kg urea ha^{-1}. In all crop rotations, perko-rice rotation presenting the maximum N use efficiency, N utilization efficiency, and N uptake efficiency was obtained with 100 kg urea ha^{-1}. Totally, it was observed that the positive effects of the cover crops in the second year was were more pronounced, where perko was more suitable than other cover crops. These findings suggest that long-term cover of these crops especially perko and buko can improve soil properties and encourage proper plant growth in paddy fields rotation, which in the long term is useful for crop production and improving qualitative parameters.

Keywords: clover, faba bean, fallow, nitrogen use efficiency.

INTRODUCTION

Sustainable intensification is a strategy to enhance resource use efficiency and productivity via its focus on soil quality, precision farming, and grain yield potential (Tilman et al., 2011). Therefore, understanding the opportunities for sustainable intensification requires an integrated assessment at field and regional levels of past development (Silva et al., 2018). Field and/or farm monitoring especially consideration of crop rotation systems and nutrient management are one of the desirable sustainable intensification ways to enhance productivity. In addition, fertilizer management can be particularly critical for profitable rice farming systems in Asia (Sharma et al., 2018), as fertilizers are typically one of the largest inputs in paddy fields.

Nitrogen (N) is one of the most important limiting factors for crop plant production in most agricultural systems (Urriola and Rathore, 2015), especially in paddy fields. Due to the critical role that nitrogen plays for yield elevation in agriculture, the global demand for nitrogen is predicted to grow by 1.3% per year from 2012 to 2016, according to the Food and Agriculture Organization (FAO) of the United Nations (Urriola and Rathore, 2015). However, while nitrogen fertilizer can contribute to enhanced productivity, they can also lead to environmental pollution (Urriola and Rathore 2015). Indeed, it is estimated that only 30-50% of applied nitrogen is taken by plants (Mc Allister et al., 2012), with the remainder causes soil, water, and air pollution (Urriola and Rathore, 2015). In addition, over the few past decades, efforts to

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enhance production per unit area have led to a significant increase in the application of various chemical fertilizers, especially nitrogen (Han et al., 2017). Recently, researchers have indicated that nitrogen use efficiency in paddy fields is related to leaching, denitrification, and sublimation at very high levels (between 30% and 40%), which also causes environmental pollution (Crews and Peoples, 2004). A sustainable cropping system should not only maintain crop production and soil nitrogen supply capacity but also reduce nitrogen runoff losses (Larkin, 2008). Crop residues can enhance organic matter, soil structure, and maintain nutrients and crop yields. Indeed, cover crop plants can be cultivated for specific purposes such as maintaining and adding nitrogen and carbon in cropping systems, improving C:N ratio, and controlling soil erosion in the paddy fields (Ghanguba et al., 2014). In this regard, three major groups of crop plant families including grasses, legumes, and *Brassicacea* are economically variable and give sustainable profitable production in rotations (Collins et al., 2007; Mukherjee, 2015). Grasses are used as green manure given their greater cold tolerance (Collins et al., 2007). Legumes, through symbiosis with Bacteria from Rhizobium genus, result in more nitrogen fixation (Collins et al., 2007). On the other hand, legumes plants are usually cultivated as green manure in the warm season because of susceptibility to cold. *Brassicacea* are also often cultivated along with legumes and grasses for the same purpose in the rotations (Collins et al., 2007). *Brassicacea* family can significantly increase organic carbon and soil porosity and control weed populations as well as soil diseases (Collins et al., 2007). Green manure crops in the rotation helps to maintain nitrogen and other nutrients, and in some cases, they help to accumulate nutrients in the field, thus preventing losses in response to leaching (Baldwin and Creamer, 2006). Further, green manure crops, in addition to controlling erosion through soil cover, are also effective in controlling pests and weeds (Baldwin and Creamer, 2006). Further, cultivation of different plants in rotation leads to enhanced microorganism activity and nitrogen mineralization process (Benintend et al., 2008). Therefore, it can be expected that use of suitable cover crops in the rotation leads to applying lower amounts of chemical fertilizers than the recommended value, while maintaining optimal rice production and increasing the sustainability of planting systems.

In a research, five crop rotation systems including fallow-rice, soybean-rice, corn-rice, soybean-corn-rice, and corn-soybean-rice rotations were investigated during seven years. The results indicated that the introduction of soybeans into the paddy fields enhanced the paddy yield, where soybean-rice rotation increased paddy yield to 920 $kg.ha^{-1}$ compared to fallow-rice rotation. Further, a soybean-rice rotation system was observed with a higher paddy yield and more efficiency than other rotation systems. Also, the NPK uptake in fallow-rice system was lower than in other crop rotation systems (Anders et al., 2004).

In the study on the rice-wheat rotation system conducted in the Punjab region, India for 14 years, the findings revealed that this system reduced the paddy yield due to the depletion of one or more elements, and the total depletion of nitrogen seems to be the most important factor in this regard (Singh et al., 2009). The cultivation of leguminous family plants has many benefits in paddy fields. Other experiments indicated that legume crops in legume-cereal rotation system led to augmented cereals yield cultivated following legumes (Ahmad et al., 2001). Yousaf et al. (2017) reported that in rice-rapeseed rotation, paddy yields were increased by 19-41% during two years of rotation with four mineral fertilizer treatments (NPK, NP, NK and PK). Further, the highest NPK contents in both crops were observed under NPK and PK treatment.

One of the best strategies to reduce the application of chemical nitrogen fertilizers in rice farming systems is to utilize the potential of biological nitrogen fixation by cultivation of leguminous plants in the legume-rice rotation (Singh et al., 2004). In temperate regions such as northern Iran, where there is no possibility of rice cultivation due to low temperatures in the fall and winter, plants from legume family such as clover and faba bean can be grown as winter crops in high-drainage paddy fields (Tabrizi et al., 2015). Further, canola-rice rotation system has also been reported in some studies (Yousaf et al., 2017), but so far there has not been any report on the rice-*Brassicacea* family crops such as perko and buko in Iran and even worldwide.

According to the finding of different studies, an average of 96% of the chemical fertilizers used in Mazandaran province are nitrogen and phosphorus fertilizers, indicating that nitrogen usage is unbalanced (Dastan et al., 2012). Meanwhile, increasing pressure to soil for higher incomes and offset for the costs of production of non-economic crops have caused soil poverty while the use of chemical fertilizers and pesticides has contaminated the water and soil. Addition of these toxic substances to groundwater, rivers, and seas is one of today's hazards which have caused severe damage and a collapse in the ecosystems' balance. Therefore, improving crop rotation systems to achieve sustainable agriculture will be one of the effective strategies through cover crops in rice cultivation in north of Iran. In this way, cover crop-rice rotations can lead enhanced productivity and less chemical fertilizer application. Accordingly, the present study aimed to investigate the effect of cover crop rotations on agronomical parameters and NK efficiency indices of rice.

MATERIAL AND METHODS

Description of the experimental site

Experiments were conducted in Sari region in Mazandaran province located in north of Iran between the Alborz Mountains and the Caspian Sea for two consecutive years 2015-16 and 2016-17. The experimental region is geographically situated at 36°4' N latitude and 52°5' E longitude.

Description of the experiment

The experiment was carried out as split plots based on a randomized complete block design (RCBD) with four replications. Six cover crop rotations including perko-rice, buko-rice, mixed cropping of berseem clover + ramtil + phaselia-rice, berseem clover-rice, faba bean-rice, and fallow-rice were used as main plots. Perco hybrid is a cross between autumn rapeseed (*Brassica napus* L. var. Napus) and Chinese cabbage (*Brassica campestris* L. var. Sensulato) and the new plant Boko amphiploid, which is the result of tetraploid cross of rapeseed (*Brassica napus* L. var. Napus) and Chinese cabbage (*Brassica campestris* L. var. Sensulato) and fodder turnip (*Brassica campestris* L. var. Rapa). Ramitil (*Guizotia abyssinica*) belongs to the *Asteraceae* family and Phacelia (*Phacelia tanacetifolia*) belongs to the *Boraginaceae* family. Also, four levels of nitrogen fertilizer including non-application (control), 50% less than recommended amount, the recommended amount based on soil analysis, and 50% more than recommended amount were 0, 50, 100, and 150 kg.ha^{-1} of urea source as subplots, respectively.

Description of the field practices

The cover crop plants were selected from *Brassicacea* family (perko and buko), two crops grown in temperate regions of Europe (ramtil and phaselia) along with two local legume crops (berseem clover and faba bean). Initially, the possibility of growth, development, and compatibility of these forage crops in the region was tested. *Brassicacea* family crops (perko and buko) and mixed cropping of ramtil + phaselia + berseem clover were planted in the main plots on November 22-23 (2015-2016, 2016-2017).

After adequate growth and suitable accumulation of dry matter of these forage crops, the forage traits were investigated on October 22-23. After sampling, the residue of these forage crops was crushed and added to paddy field with minimum tillage to improve the decay of residue and enhance the organic matter content to the paddy soil before rice transplantation.

The cover of berseem clover and faba bean was done in main plots on October 22-23 (2015-2016, 2016-2017). Clover, after two harvesting (first and second cutting), was returned to paddy soil on April 21-30 before the third cutting as a green manure. The faba bean was also harvested during maturity stage on May 5-8 whose residue was added to the soil. Then, paddy field preparation practices were done based on the nitrogen fertilizer treatments.

Nursery preparation was performed in the first and second year on April 9-10 and on April 14-15, respectively. To prevent nitrogen leaching and weed growth in paddy fields, nylon plastic cover was put at the borders to a depth of 30 cm. considering the regional climates, 'Tarom Hashemi' cultivar was transplanted with three seedlings per hill (young seedling with 3-5 leaves) by 25 plants per square meter with planting arrangement of 20×20 cm^2. Transplanting was done during the first and second years on May 26-27 and on May 30-31, respectively. Nitrogen was applied according to the fertilizer treatment. One third of nitrogen fertilizer was used as basal during puddling. Two thirds of nitrogen fertilizer were used as top-dressing in panicle initiation and full heading stages. Phosphorous and potassium fertilizers were employed in each plot according to the suggestion of Rice Research Institute of Iran (RRII) and by considering the result of soil analysis. The entire phosphorus content (100 $kg.ha^{-1}$) and 60% of potassium fertilizer (60 $kg.ha^{-1}$) were used as basal, while the remaining amount of potassium was consumed as top-dressing in tillering stage (20 $kg.ha^{-1}$) and panicle initiation stage (20 $kg.ha^{-1}$). Further, the depth of irrigation was set at 5 cm according to agricultural principles. Crop protection practices, such as irrigation, weeding, pests and diseases control, and fertilization, were done in the experiment paddy field based on technical instruction of Rice Research Institute of Iran (RRII).

Measurement

During the growth period, after the removal of marginal effect, traits were randomly measured according to the Standard Evaluation System (SES) of the International Rice Research Institute (IRRI). Thus, 10 tillers per hill were randomly selected from each experimental plot whose average was analyzed. The total N concentration in grain and straw was determined by the micro-Kjeldahl method. Potassium concentration was determined by a flame photometer. The parameters evaluated included grain harvest index (Eq. 1), NK uptake in grain, NK uptake in straw, NK harvest index (Eq. 2), NK use efficiency (Eq. 3), NK agronomic efficiency (Eq. 4), NK physiological efficiency (Eq. 5), NK apparent recovery efficiency (Eq. 6), NK utilization efficiency (Eq. 7), and NK uptake efficiency (Eq. 8) (Fageria et al., 2014; Lopez-Bellido et al., 2005).

$$GHI\ (\%) = (GY/(GY+SY) \qquad [1]$$

where, GHI = Grain harvest index, GY = Grain yield and SY = Straw yield.

$$NKHI\ (\%) = [UNKG/(UNKG+UNKS)] \qquad [2]$$

where, NKHI = N and K harvest index, UNKG = Uptake of N and K in grain, and UNKS = Uptake of N and K in straw.

$$NKUE\ (kg.ha^{-1}) = W_g/NK_f \qquad [3]$$

where, W_g = Grain weight and N_f = Quantity of N and K applied (kg).

$$AE\ (kg.ha^{-1}) = [(GY_f\text{-}GY_{uf})/NK_f\,] \qquad [4]$$

where, GY_f = Grain yield of fertilized plot, GY_{uf} = Grain yield of unfertilized plot and NK_f = Quantity of N and K applied (kg).

$$PE\ (kg.ha^{-1}) = [(BY_f\text{-}BY_{uf})/(UNK_f\text{-}NK_{uf})] \qquad [5]$$

where, BY_f = Biological yield (grain + straw) of fertilized plot, BY_{uf} = Biological yield of unfertilized plot, UNK_f = Uptake of N and K (kg) in grain plus straw of fertilized plot and UNK_{uf} = Uptake of N and K (kg) in grain and straw of unfertilized plot.

$$ARE\ (\%) = [(UNK_f\text{-}UNK_{uf})/NK_f]\times 100 \qquad [6]$$

where, UNK_f = Uptake of N and K (kg) in fertilized plot, UNK_{uf} = Uptake of N and K (kg) in unfertilized plot and NK_f = Quantity of N and K applied (kg).

$$UE\ (kg.ha^{-1}) = ARE\times PE \qquad [7]$$

$$UPE\ (kg.ha^{-1}) = NK_t/NK_f \qquad [8]$$

where, N^t = Total N and K uptake by grain, NK_f = Quantity of N and K applied (kg).

Statistical analysis

All statistical analyses were performed using the SAS software. A two-way analysis of variance (ANOVA) was used by GLM procedure and the least significant difference (LSD) test was employed to compare the differences between treatment means at a 5% probability level.

RESULTS AND DISCUSSION

Combined analysis of variance (ANOVA)

The combined variance analysis and mean comparisons is presented in Tables 1, 2 and 3.

Table 1. Combined analysis of variance (ANOVA) and mean comparison of studied traits of rice related to cover crop rotation and nitrogen application

SOV		PL	TTH	FTH	TSP	FSP	GY	GHI
		Mean square (ANOVA)						
Year (Y)		*	**	**	**	**	**	**
Crop rotation (C)		**	**	**	**	**	**	**
Nitrogen (N)		*	ns	ns	ns	ns	**	*
C × N		*	ns	ns	ns	ns	**	*
CV (%)		4.22	7.75	9.02	9.74	14.85	6.36	3.87
		Mean comparison						
Year	First year (2015-16)	26.30 b	14.01 b	9.93 b	98.91 b	92.61 b	4291 b	43.05 b
	Second year (2016-17)	26.69 a	18.70 a	12.81 a	108.85 a	95.79 a	4535 a	44.16 a
LSD 0.05		0.37	0.42	0.34	3.36	2.35	93.23	0.56
Cover crop rotation	Perko-rice	28.92 a	16.42 c	11.83 b	103.13 b	93.46 b	4531 ab	44.15 a
	Buko-rice	28.63 a	18.46 a	12.83 a	100.17 b	89.12 c	4685 a	42.45 b
	Mixed cropping-rice	28.70 a	15.73 c	10.72 c	93.33 c	88.08 c	4514 b	43.87 a
	Clover-rice	24.12 b	15.81 c	10.61 c	110.41 a	100.06 a	4291 c	44.59 a
	Faba bean-rice	24.50 b	17.44 b	12.50 a	105.68 ab	93.47 b	4176 c	41.98 b
	Fallow-rice	24.11 b	14.27 d	9.72 d	110.55 a	101.02 a	4281 c	44.59 a
LSD 0.05		0.64	0.73	0.59	5.83	4.06	161.47	0.97
Nitrogen (kg urea ha^{-1})	0	26.21 b	16.04 a	11.14 a	101.32 a	92.68 b	4273 b	42.96 b
	50	26.56 ab	16.51 a	11.50 a	104.40 a	93.67 ab	4532 a	43.99 a
	100	26.87 a	16.51 a	11.47 a	105.92 a	96.25 a	4434 a	43.85 a
	150	26.34 b	16.35 a	11.37 a	103.88 a	94.20 ab	4413 a	43.60 ab
LSD 0.05		0.52	0.60	0.48	4.76	3.32	131.84	0.79
PL: panicle length (cm)		TTH: number of tiller per hill		FTH: number of fertile tiller per hill		TSP: number of spikelet per panicle		
FSP: filled spikelet percentage		GY: grain yield (kg ha^{-1})		GHI: grain harvest index (%)				

†: ns, * and ** show non-significant and significant at 5% and 1% of probability levels, respectively.
††: values within a column followed by same letter are not significantly different at least significant differences (LSD) test (0.05).
SOV is source of variation; and CV is the coefficient of variation which was related to overall data.

Table 2. Combined analysis of variance (ANOVA) and mean comparison of studied traits of rice related to cover crop rotation and nitrogen application

SOV		GNU	PNU	PY	NAE	NPE	NARF	NUE^a	NUE^b	NUE^c	NHI
		Mean square (ANOVA)									
Year (Y)		**	**	**	ns	Ns	Ns	**	**	*	**
Crop rotation (C)		**	**	**	**	**	**	**	**	**	**
Nitrogen (N)		ns	ns	ns	**	*	**	**	ns	**	ns
C × N		ns	ns	ns	**	**	Ns	**	*	*	ns
CV (%)		12.34	12.43	12.34	21.43	29.30	16.99	9.56	13.54	21.31	7.30
		Mean comparison									
Year	First year (2015-16)	71.61 a	111.08 a	426.11 a	2.07 a	213.91 a	-76.50 a	42.30 a	42.51 b	0.66 a	64.50 b
	Second year (2016-17)	66.24 b	92.40 b	394.11 b	1.80 a	163.32 a	-72.39 a	39.90 b	47.04 a	0.61 a	72.20 a
LSD 0.05		2.83	4.20	16.82	1.38	187.78	4.20	1.30	2.01	0.04	1.66
Cover crop rotation	Perko-rice	76.97 a	108.13 b	457.99 a	-2.33 c	-416.40 c	-73.60 b	40.62 bc	42.58 c	0.71 a	71.64 a
	Buko-rice	78.05 a	117.87 a	464.37 a	4.42 ab	813.20 a	-63.71 a	44.80 a	40.91 c	0.73 a	67.41 bc
	Mixed cropping-rice	60.39 c	93.45 c	359.32 c	2.47 b	396.70 b	-79.48 bc	41.78 b	50.98 a	0.53 c	65.12 c
	Clover-rice	65.86 b	93.28 c	391.88 b	6.59 a	1039.30 a	-72.62 b	41.67 b	46.44 b	0.63 b	71.15 a
	Faba bean-rice	67.97 b	104.18 b	404.39 b	2.14 b	170.30 b	-81.99 c	39.17 c	41.45 c	0.62 b	65.68 c
	Fallow-rice	64.32 bc	93.54 c	382.71 bc	-1.71 c	-871.40 d	-75.28 bc	38.54 c	46.30 b	0.59 bc	69.07 ab
LSD 0.05		4.90	7.28	29.13	2.38	325.25	7.28	2.26	3.49	0.08	2.87
Nitrogen (kg urea ha^{-1})	0	69.19 a	101.19 a	411.67 a	0.00 b	0.00 b	0.00 a	0.00 d	43.10 b	0.00 d	68.85 a
	50	70.10 a	103.21 a	417.08 a	5.18 a	384.60 a	-47.98 b	90.63 a	46.06 a	1.40 a	68.71 a
	100	67.33 a	100.62 a	400.60 a	1.61 b	181.40 ab	-100.57 c	44.34 b	45.78 ab	0.67 b	67.48 a
	150	69.09 a	101.95 a	411.08 a	0.93 b	188.40 ab	-149.23 d	29.42 c	44.17 ab	0.46 c	68.34 a
LSD 0.05		4.00	5.94	23.79	1.95	265.57	5.94	1.85	2.85	0.06	2.34

GNU: grain nitrogen uptake (kg ha^{-1}); PNU: plant nitrogen uptake (kg ha^{-1}); NAE: Nitrogen agronomic efficiency (kg kg^{-1}); NUE^c: nitrogen uptake efficiency (kg ha^{-1})
NHI: nitrogen harvest index (%); NARF: nitrogen apparent recovery fraction (%); NUE^a: nitrogen use efficiency (kg ha^{-1})
PY: protein yield (kg ha^{-1}); NPE: nitrogen physiological efficiency (kg kg^{-1}); NUE^b: nitrogen utilization efficiency (kg ha^{-1})

†: ns, * and ** show non-significant and significant at 5% and 1% of probability levels, respectively.
††: values within a column followed by same letter are not significantly different at least significant differences (LSD) test (0.05).
SOV is source of variation; and CV is the coefficient of variation which was related to overall data.

Table 3. Combined analysis of variance (ANOVA) and mean comparison of studied traits of rice related to cover crop rotation and nitrogen application

SOV		GKU	PKU	KAE	KPE	KARF	KUE^{a}	KUE^{b}	KUE^{c}	KHI
		Mean square (ANOVA)								
Year (Y)		**	**	Ns	Ns	Ns	**	**	**	ns
Crop rotation (C)		**	**	**	**	**	**	**	*	ns
Nitrogen (N)		ns	ns	**	*	Ns	**	*	**	*
C × N		ns	ns	**	**	Ns	**	ns	ns	ns
CV (%)		22.97	15.67	21.43	29.44	11.50	6.36	17.52	37.82	17.76
		Mean comparison								
Year	First year (2015)	20.84 b	85.41 b	2.07 a	212.96 a	0.09 a	45.35 a	56.21 a	0.20 b	24.84 a
	Second year (2016)	29.29 a	119.21 a	1.80 a	170.14 a	-5.19 a	42.91 b	37.75 b	0.27 a	24.81 a
LSD 0.05		1.86	5.33	1.38	187.34	9.75	0.93	2.73	0.03	1.47
Cover crop rotation	Perko-rice	24.37 bc	103.05 bc	-2.32 c	-412.80 c	-2.60 ab	45.31 ab	47.49 b	0.23 ab	24.17 ab
	Buko-rice	28.89 a	122.98 a	4.42 ab	815.00 a	13.43 a	46.85 a	40.25 c	0.28 a	23.27 b
	Mixed cropping-rice	25.51 b	97.75 c	2.47 b	393.60 b	-2.07 ab	45.14 b	50.64 ab	0.24 ab	26.13 a
	Clover-rice	21.92 c	86.99 d	6.59 a	1035.90 a	7.39 a	42.91 c	54.00 a	0.20 b	25.57 ab
	Faba bean-rice	26.10 ab	109.24 b	2.14 b	175.4 b	-13.16 b	41.76 c	41.36 c	0.24 ab	24.19 ab
	Fallow-rice	23.60 bc	93.85 cd	-1.71 c	-857.80 d	-18.29 b	42.81 c	48.12 b	0.21 b	25.64 ab
LSD 0.05		3.22	9.23	2.38	324.48	16.88	1.61	4.74	0.05	2.54
Nitrogen (kg urea ha^{-1})	0	23.90 a	104.70 a	0.00 b	0.00 b	0.00 a	42.73 b	44.00 b	0.00	23.29 b
	50	25.47 a	103.25 a	5.18 a	388.10 a	-2.90 a	45.32 a	48.27 a	0.51 a	25.04 ab
	100	25.81 a	98.96 a	1.61 b	186.60 ab	-5.74 a	44.34 a	49.60 a	0.26 b	26.38 a
	150	25.09 a	102.34 a	0.93 b	191.50 ab	-1.57 a	44.13 a	46.04 ab	0.17 c	24.60 ab
LSD 0.05		2.63	7.53	1.95	264.94	13.78	1.32	3.87	0.04	2.07
GKU: grain potassium uptake (kg ha^{-1})		PKU: plant potassium uptake (kg ha^{-1})					KAE: potassium agronomic efficiency (kg kg^{-1})			
KPE: potassium physiological efficiency (kg kg^{-1})		KARF: potassium apparent recovery fraction (%)					KUE^{a}: potassium use efficiency (kg ha^{-1})			
KUE^{b}: potassium utilization efficiency (kg ha^{-1})		KUE^{c}: potassium uptake efficiency (kg ha^{-1})					KHI: potassium harvest index (%)			

†: ns, * and ** show non-significant and significant at 5% and 1% of probability levels, respectively.
††: values within a column followed by same letter are not significantly different at least significant differences (LSD) test (0.05).
SOV is source of variation; and CV is the coefficient of variation which was related to overall data.

Agronomic traits, grain yield, and harvest index

Mean comparison of year × crop rotation by slice interaction revealed that the largest panicle length in both years was obtained for crop rotation of perko-rice, buko-rice, and mixed cropping-rice (Table 1). On the other hand, the minimum panicle length in both years was observed for clover-rice, faba bean-rice, and fallow-rice rotations respectively. According to the findings, panicle length in crop rotations was higher for the second year than for the first year. Further, the number of tillers per hill and the number of fertile tillers per hill in perko-rice rotation for both years were the maximum followed by buko-rice along with mixed cropping-rice. Fallow-rice rotation led to minimum number of tillers per hill and number of fertile tillers per hill for both years. Furthermore, the same results were observed for the number of spikelets per panicle and the number of filled spikelets per panicle in both years. In addition, the largest number of spikelets per panicle was obtained for perko-rice, buko-rice, and mixed cropping-rice in the both years, followed by while clover-rice and faba bean-rice rotations. On the other hand, fallow-rice rotation led to the fewest spikelets per panicle in both years as 84.72 and 101.93 spikelets, respectively. The highest filled spikelet percentage in the first year (44.93%) belonged to buko-rice rotation, but in the second year, the maximum value of this trait was related to perko-rice, buko-rice, and mixed cropping-rice rotations, respectively, which were equal to 90.06%, 89.34%, and 89.13%. Indeed, the maximum number of spikelets per panicle was related to perko-rice and buko-rice rotations. In this regard, mixed cropping-rice and clover-rice rotations claimed the next ranks. Fallow-rice rotation led to minimum filled spikelet percentage in both years (Table 1). According to the findings, it was observed that the positive effects of the cover were more pronounced in the second year compared to the first year which led to enhanced panicle length, number of tiller per hill, number of fertile tillers per hill, number of spikelets per panicle, and number of filled spikelets per panicle. These results indicated that the long-term cover of crops can improve soil properties and encourage proper growth of crop plants in the rotation.

Double interaction of cop rotation × nitrogen application was described for panicle length, paddy yield, and harvest index. Across all the crop rotation levels, with elevation of N rate, panicle length and paddy yield increased statistically which with perko-rice, buko-rice and mixed cropping-rice being the first, second and third, respectively (data not shown) in this regard. They were followed by clover-rice and faba bean-rice, while the minimum panicle length and paddy yield were obtained in fallow-rice rotation. The shortest panicle length in perko-rice, buko-rice, mixed cropping-rice, and clover-rice rotations was observed for zero N treatment. However, the longest panicle was obtained for other N rates. Panicle length in faba bean-rice and fallow-rice rotations was statistically shorter for all N rates than in other rotations (data not shown).

Regarding the findings of yield components, the highest paddy yield (5147 kg.ha^{-1}) was achieved in perko-rice rotation with nitrogen application 50% more than the recommended rate (data not shown). It was followed by buko-rice and mixed cropping-rice rotations with application of 150 kg urea.ha^{-1}, respectively. Totally, the highest paddy yield was produced for rotations of perko-rice, buko-rice, and mixed cropping-rice via applying 150 kg urea.ha^{-1}. In addition, in these crop rotations, application of 100 and 50 kg urea.ha^{-1} claimed the next ranks, respectively. In faba bean-rice rotation, the highest paddy yield (4514 kg.ha^{-1}) was produced with application of 150 kg urea.ha^{-1}. It was followed by application of 100 and 50 kg urea.ha^{-1}. Fallow-rice rotation along with zero N application revealed the minimum paddy yield (3827 kg.ha^{-1}) (data not shown). Based on the findings of crop rotation × nitrogen interaction, the highest grain harvest index (47.01%) was found in fallow-rice rotation with application of 50 kg urea.ha^{-1}. On the other hand, the minimum grain harvest index was obtained for perko-rice with 100 kg urea.ha^{-1}. Perko-rice rotation was followed by clover-rice and faba bean-rice rotations with zero N application along with fallow-rice rotation with 150 kg urea.ha^{-1} (data not shown). It seems that in the second year of experiment, cover crop plants with a more positive effect on soil organic matter resulted in improved physical properties of the soil and enhanced activity of soil microorganisms which led to augmented paddy yield and yield components.

Triple interaction of year × crop rotation × nitrogen by slice interaction indicated that for all crop rotations, the highest plant height was achieved with 150 and 100 kg urea.ha^{-1} in both years (Table 1). Based on the findings, cover crop plants had a higher positive effect in the second year which caused the improvement of rice growth parameters.

NK related indices

According to the mean comparison of year × crop rotation by slice interaction, the maximum grain N uptake in both years was obtained for perko-rice rotation and buko-rice rotations, which were followed by mixed cropping-rice, clover-rice and faba bean-rice rotations, respectively. However, the least grain N uptake in both years (61.63 and 59.15 kg.ha^{-1}) was achieved in fallow-rice rotation. Furthermore, plant N uptake in perko-rice rotation was highest for both years. On the other hand, the minimum plant N uptake was observed in fallow-rice rotation (83.61 and 91.28 kg.ha^{-1}) in both years. The most protein yield was observed in perko-rice rotation (442.78 kg.ha^{-1}) in first year, but, this parameter in buko-rice rotation decreased by 3.29% (Table 2). Based on the findings, the highest N harvest index was obtained in perko-rice, buko-rice, and mixed cropping-rice rotations for both years. The least N harvest index (60.04% and 67.19%) was observed in fallow-rice rotation. In addition, the maximum N utilization efficiency (54.49 and 49.99 kg.ha^{-1}) was achieved in perko-rice rotation for both years, which was followed by other rotations (Table 2). In year × crop rotation by slice interaction, the largest plant K uptake was achieved in perko-rice rotation (101.53 and 144.43 kg.ha^{-1}) for both years. On the other hand, the minimum amount was calculated in fallow-rice rotation (63.79 and 95.86 kg.ha^{-1}) for both years. The highest K utilization efficiency was obtained in perko-rice rotation for the both years, followed by buko-rice rotation (Table 2).

Based on the interaction of crop rotation × nitrogen, the highest N use efficiency, N utilization efficiency, N uptake efficiency, and K use efficiency were found in perko-rice rotation with application of 150 kg urea.ha^{-1} (data not shown). According to the findings, it was found that in all crop rotations, NK investigated indices (grain N content, plant N content, N use efficiency, N utilization efficiency, N uptake efficiency, grain K content and K use efficiency) were enhanced with application of 150 kg urea.ha^{-1} which was followed by the recommended N rated (Table 2).

The findings of year × crop rotation × nitrogen by slice interaction demonstrated that in all the crop rotations, the highest K harvest index and K uptake efficiency were observed with 150 kg urea.ha^{-1} for both years (Table 3). The lower K harvest index and K uptake efficiency in all the crop rotations was obtained for zero N rate for both years. Totally, NK investigated indices for perko-rice rotation was significantly higher than other crop rotations for both years which was followed by buko-rice rotation and mixed cropping-rice rotation. In addition, clover-rice and faba bean-rice rotations claimed the fourth and fifth ranks in terms of NK indices, respectively (Table 2). Therefore, based on the findings, all the cover crop plants had a higher positive effect in the second year compared to the first year causing rice qualitative parameters to improve.

In general, the findings of this research revealed that although all of the cover rotations with nitrogen application led to augmented paddy yield, as well as improved growth and quality conditions, the addition of *Brassicacea* family crops (perko and buko) increased soil organic matter and the amount of available nitrogen for rice more than the legumes did (clover and faba bean), which led to enhanced nutrient uptake and paddy yield compared to mixed cropping-rice, clover-rice, and faba bean-rice rotations. It seems that cover of perko and buko in the region can lead to provision of forage and improvement of the soil organic matter which is useful for improving the soil structure and improving the quantitative and qualitative yield of rice in the long term. Generally, the results demonstrated that in the case of rice-legumes rotation, the effect of clover on rice yield rise was significantly higher as compared to faba bean. In addition, increasing the amount of nitrogen from 50% to 100% of the recommended rate per hectare resulted in enhancement of paddy yield. However, application of nitrogen higher than the recommended rate resulted in luxury usage which had a negative impact on quantitative and qualitative parameters of rice. According to the results of this study, clover cultivation before rice with 100 kg of urea per hectare is recommended to achieve maximum paddy yield.

In the perko-rice and buko-rice rotations, due to the high day matter of these two cover plants, more residues were added to the soil, and the high nitrogen content of these residues led to the improvement of soil organic matter and higher uptake of nitrogen by the soil compared to other cover crops. As a result, NK uptake and protein yield of rice was enhanced in these crop rotations, where in the second year its positive effect was higher than in the first year. Hence, in fallow-rice rotation, the lack of crops residue in the soil, the rice plant utilized a large portion of nitrogen from fertilizer and produced a higher yield per unit of chemical fertilizer. These findings suggest that in fallow-rice rotation because of diminished soil fertility and limited production factors, the reaction to nitrogen uptake was higher. In this regard, other researchers also reported that the interaction of crop rotation × nitrogen fertilizer increased the nutrient uptakes in the crop plants (Thuy et al., 2008). Lopez-Bellido and Lopez-Bellido (2001) found that nitrogen productivity was varied across different crop rotations depending on the amount of nitrogen usage; with increased nitrogen application, the nitrogen productivity decreased. Further, increasing nitrogen application from 50% to 100% of the recommended amount showed a significant increase in the nitrogen content, while more nitrogen (100% of recommended amount) did not significantly increase the grain nitrogen content (Lopez-Billido et al., 2004).

The findings of this research indicated that crops grow and establish where soil nutrients tend to be improved by cover crops or fertilizer and manure applications. The finding agrees with Nasiri et al. (2008); they observed variation in rice parameters, where rice was transplanted after different legumes. Anders et al. (2004) demonstrated that paddy yield in soybean-rice rotation was higher than in wheat-rice rotation. This result was obtained by Becker and Johnson (1998) where paddy yield in legume-rice rotation system was 30% higher than in fallow-rice rotation system. Indeed, after microbial decomposition of crop plant residues, nutrients remain within the crop tissues and nutrient rich dead microbes, which are released and made available to the following crop (Wichern et al., 2008). In this regard, Franke et al. (2008) reported that forage legume (*Stylosanthes guianensis*) - maize dual-purpose soybean-maize rotations produced a higher yield than fallow-maize rotation. Kayser et al. (2010) reported that the effect of arable legumes was rather short lived while three-year plough of grassland leys had a greater influence on mineralization process and subsequently on yield and nitrogen losses. Note that in our study, all cover crops were added into soil. Based on the findings, this could slightly slow the breakdown of cover crop residues resulting in poor volatile loss of ammonia during rice in rotation with all cover crops growing cycle. However, in fallow-rice rotation systems with nitrogen application, a substantial amount of nitrogen is seemingly lost by leaching and volatilization. Rahman et al. (2014) reported that regardless of fertilizers, legume-rice rotation system achieved more NRE than corn-rice rotation system in two years. Further, in India, a great variation in NRE (18-49% in two years) was obtained in wheat-rice system (Balota et al., 2003). In addition, higher NRE was reported in crop rotation than sole culture (Cazzato et al., 2012).

The higher nitrogen and potassium recovery in all the cover crop rotations might be due to the enrichment of soil. Indeed, the below ground pool of nutrient, especially nitrogen, is an important source of nitrogen in cover crops especially legumes for subsequent crops. Other researchers reported similar findings for legumes crop (Wichern et al., 2008). They announced that when the soil nitrogen content rises, the amount of sequestered nitrogen achieved from nitrogen usage results in a higher NRE (Wichern et al., 2008). Thus, emphasis has been given to improve recovery efficiency of nitrogen as the chemical nitrogen is the greatest source of nitrogen fertilizer and loss of cereal cropping systems, especially in paddy field cropping systems. In this regard, other researchers reported that NUE was reduced with high application of chemical nitrogen fertilizer, possibly due to greater losses from soil through volatilization or leaching process (Cazzato et al., 2012).

With respect to chemical nitrogen application in paddy fields, current nitrogen application strategies should be improved in paddy field cropping systems. Our findings suggested that all cover crop residues, especially perko, buko and mixed cropping residue, had a positive influence on paddy yield as well as both nitrogen and potassium uptake when fertilizer was not used. Indeed, the effect of cover crops residue on the soil nutrient status, texture, addition of organic matter, amount of residue returned to soil (Motior et al., 2011), and timing and amounts of nitrogen fertilizer used. Furthermore, nitrogen significantly improved plant height, panicle length, grain HI and nitrogen HI which is positively associated with paddy yield. Similar results were found by Fageria (2007) and Fageria et al. (2011). In this regard, Meelu et al. (1979) reported that higher chemical nitrogen utilized to wheat-rice rotation was immobilized in the organic form than wheat-maize rotation. Meanwhile, Brassica species are important to control weeds and pests because of the allelochemicals they release (Yasumoto et al., 2010). Ren et al. (2015) reported that under recommended fertilization rapeseed seed yield in rice-rapeseed rotation was higher than cotton-rapeseed rotation. However, without nitrogen fertilization, rapeseed yield in rice-rapeseed rotation was significantly lower than in cotton-rapeseed rotation. Similar findings were reported for other crops (Singh et al., 2009; Yamada et al., 2010), although rapeseed yields varied under different environment conditions (Sidlauskas and Bernotas, 2003). Other researchers demonstrated that because of higher nitrogen losses from runoff and ammonia volatilization during the rice season (Zhao et al., 2009), the flooded rice production soil contained significantly lower accumulated mineral nitrogen contents after harvest (Fan et al., 2007).

Mohammadi et al. (2011) demonstrated that nitrogen uptake in the green manure utilization was one of the most effective factors in increasing the crop production. Further, crop rotation led to improved soil fertility (Yadvinder-Singh et al., 2004). Indeed, improving water use efficiency (Christen and Sieling, 1995), control of diseases and pests (Larkin, 2008), and increasing soil biological activity (Larkin, 2008) are the main cause for enhancing crop production in the rotation. In addition, crop rotation reduces chemical fertilizer utilization. Further, applying crop rotation along with nitrogen application increased biodiversity, soil biological community, and agroecosystems' health (Kamkar and Mahdavi Damghani, 2009). Unfortunately, because of farmers' economic problems, crop rotation is restricted in Iran, especially in paddy fields, and most farmers cannot achieve long-term goals during the transition to sole cropping, simpler rotations, or chemical inputs application meet to short time-targets (Kamkar and Mahdavi Damghani, 2009).

CONCLUSIONS

The findings of the study demonstrated that residue of all the cover crops and application of nitrogen fertilizer significantly affected the paddy yield, yield components, lodging index, plant NK content, plant NK uptake, NK efficiency, and NK harvest index. All of the above parameters in the second year were significantly higher than the first year. All the cover crop rotations (Perko-rice, buko-rice, mixed cropping-rice, clover-rice and faba bean rice) produced significantly greater paddy yield and NK use efficiency than fallow-rice rotation. However, paddy yield and NK use efficiency declined with application of 150 kg urea.ha^{-1}. These findings indicated that all the cover crops-rice rotations, especially perko, buko and mixed cropping, played a significant role in enhancement of paddy yield.

Although excessive nitrogen application (more than the recommended rate) increases the overall system performance, it leads to a reduction in NK efficiency. Finally, with increasing nitrogen uptake, the efficiency of nitrogen recovery to optimum use of nitrogen fertilizer increased and then decreased. Since at the moment the average rice production in the region via applying the recommended amount of fertilizer is less than 5 tons paddy yield per hectare, it can be stated that perko-rice and buko-rice rotations, are suitable recommended alternatives in the region because of high paddy yield with less fertilizer application. Indeed, the total paddy yield in these rotations with the recommended nitrogen application was greater than other alternatives studied. Therefore, among the tested cover crops, perko, buko and mixed cropping demonstrated the greatest potential, while the clover, faba bean, and fallow also were used as substitutes or supplements instead of chemical/inorganic nitrogen fertilizer application.

REFERENCES

Ahmad, W., Shah, Z., Jamal, M., Shah, K.A., 2014. *Recovery of organic fertility in degraded soil through fertilization and crop rotation.* J. Saudi. Soc. Agric. Sci., 13(2): 92-99. doi:10.1016/j.jssas.2013.01.007

Anders, M.M., Winham, T.E., Watkins, K.B., Moldehaner, K.A.K., Mcnew, R.W., Holchaver, J., 2004. *The effect of rotation, tillage, fertility and variety on rice yield and nutrient uptake.* Proceedings of the 26th Southern Conservation Tillage Conference for Sustainable Agriculture, Releigh, North Carolina, USA: 26-33.

Baldwin, K.R., and Creamer, N.G., 2006. *Cover Crops for Organic Farms*. North Carolina Cooperative Extension Service Publications Available on-line at: http:// www. Cefs. Ncsu.Edu/PDFs/Updated /Cover crops FINAL Pdf Jan 2009.pdf.

Balota, E.L., Colozzi-Filho, A., Andrade, D.S., Dick, R.P., 2003. *Microbial biomass in soils under different tillage and crop rotation systems*. Biol. Fertil. Soil, 38(1): 15-20. doi:10.1007/s00374-003-0590-9

Becker, M., and Johnson, D.E., 1998. *Legumes as dry season fallow in upland rice-based systems of West Africa.* Biol. Fertil. Soil, 27: 358-367. doi:10.1007/S003740050444

Benintend, M.C., Sterren, M.A., Battista, J.J.D., 2008. *Soil microbiological indicators of soil quality in four rice rotation system*. Ecol. Indic., 8(5): 704-708.

Cazzato, E., Tufarelli, V., Ceci, E., Stellacci, A.M., Laudadio, V., 2012. *Quality, yield and nitrogen fixation of faba bean seeds as affected by sulphur fertilization*. Acta Agric. Scandinavica B: Soil Plant Sci. 62(8): 732-738. doi:10.1080/09064710.2012.698642

Christen, O., and Sieling, K., 1995. *Effect of different preceding crops and crop rotations on yield of winter oilseed rape (Brassica napus L).* Crop Sci. 174(4): 265-271. doi:10.1111/j.1439-037X.1995.tb01112.x

Collins, H.P., Delgado, J.A., Alva, A.K., Follett, R.F., 2007. *Use of nitrogen-15isotopic techniques to estimate nitrogen cycling from a mustard cover crop to potatoes*. Agron. J., 99(1): 27-35.

Crews, T.E., and Peoples, M.B., 2004. *Legume versus fertilizer sources of nitrogen: ecological tradeoffs and human needs*. Agric. Ecosyst. Environ., 102: 279-297. doi:10.1016/j.agee.2003.09.018

Dastan, S., Siavoshi, M., Zakavi, D., Ghanbari, A., Yadi, R., Ghorbannia, E., Nasiri, A.R., 2012. *Application of nitrogen and silicon rates on morphological and chemical lodging related characteristics in rice (Oryza sativa L.) north of Iran.* J. Agric. Sci., 4(6): 12-18. doi:10.5539/jas.v4n6p12

Fageria, N.K., 2007. *Yield physiology of rice*. J. Plant Nutr., 30(6): 843-879. doi:10.1080/15226510701374831

Fageria, N.K., Dos Santos, A.B., Coelho, A.M., 2011. *Growth, yield and yield components of lowland rice as influenced by ammonium sulphate and urea fertilization.* J. Plant. Nutr., 34(3): 371-386. doi:10.1080/01904167.2011.536879

Fageria, N.K., Gheyi, H.R., Carvalho, C.S., 2014. *Yield, potassium uptake, and use efficiency in upland rice genotypes.* II INOVAGRI International Meeting, 13-16 April, Fortaleza, Brazil: 4515-4520.

Fan, M.S., Lu, S.H., Jiang, R.F., Liu, X.J., Zeng, X.Z., Goulding, K.W.T., Zhang, F.S., 2007. *Nitrogen input, 15N balance and mineral N dynamics in a rice-wheat rotation in southwest China.* Nutr. Cycl. Agroecosyst., 79(3): 255-265. doi:10.1007/s10705-007-9112-8

Franke, A.C., Laberge, G., Oyewole, G.B., Schulz, S., 2008. *A comparison between legume technologies and fallow, and their effects on maize and soil traits, in two distinct environments of the West African savannah*. Nutr. Cycl. Agroecosyst., 82: 117-135. doi:10.1007/s10705-008-9174-2

Ghanguba, A.U., Kolo, M.G.M., Odofin, A.J., Gana, A.S., 2014. *Performance of rice grown after cassava/legume intercrops at badeggi in the Southern Guinea Savanna*. Ecol. Zone NGA, 3(1): 1-5. doi:10.4172/2375-4338.1000129

Han, Z., Todd Walter, M., Drinkwater, L.E., 2017. *N_2O emissions from grain cropping systems: a meta-analysis of the impacts of fertilizer-based and ecologically-based nutrient management strategies*. Nutr. Cycl. Agroecosyst., 107: 335-355. doi:10.1007/s10705-017-9836-z

Kamkar, B., and Mahdavi Damghani, A., 2009. *Principles of sustainable agriculture*. Ferdowsi University Press, Mashhad, Iran. (In Persian)

Kayser, M., Muller, J., Isselstein, J., 2010. *Nitrogen management in organic farming: comparison of crop rotation residual effects on yields, N leaching and soil conditions.* Nutr. Cycl. Agroecosyst., 87: 21-31. doi:10.1007/s10705-009-9309-0

Larkin, R.P., 2008. *Relative effects of biological amendments and crop rotations on soil microbial communities and soil borne diseases of potato*. Soil Biol. Biochem., 40: 1341-1351. doi:10.1016/j.soilbio. 2007.03.005

Lopez-Bellido, R.J., and Lopez-Bellido, L., 2001. *Efficiency of nitrogen in wheat under Mediterranean condition: effect of tillage, crop rotation and N fertilization*. Field Crops Res., 71(1): 31-46. doi: 10.1016/S0378-4290(01)00146-0

Lopez-Bellido, R.J., Lopez-Bellido, L., Castillo, J.E., Lopez-Bellido, F.J., 2004. *Chickpea response to tillage and soil residual nitrogen in a continuous rotation with wheat II. Soil nitrate, N uptake and influence on wheat yield*. Field Crops Res., 88(2/3): 191-200. doi: 10.1016/j.fcr.2004.01.011

Lopez-Bellido, L., Lopez-Bellido, R.J., Redondo, R., 2005. *Nitrogen efficiency in wheat under rainfed Mediterranean conditions as affected by split nitrogen application*. Field Crops Res., 94(1): 86-97. doi: 10.1016/j.fcr.2004.11.004

McAllister, C.H., Beatty, P.H., Good, A.G., 2012. *Engineering nitrogen use efficient crop plants: the current status.* Plant Biotech J., 10: 1011-1025. doi: 10.1111/j.1467-7652.2012.00700.x

Meelu, O.P., Beri, V., Sharma, K.N., Jalota, S.K., Sandhu, B.S., 1979. *Influence of paddy and corn in different rotations on wheat yield, nutrient removal and soil properties*. Plant Soil, 51: 51-57. doi: 10.1007/BF02205926

Mohammadi, K., Ghalavand, A., Aghaalikhani, M., Heidari, G., Shahmoradi, B., Sohrabi, Y., 2011. *Effect of different methods of crop rotation and fertilization on canola traits and soil microbial activity.* Aust. J. Crop Sci., 5(10): 1261-1268.

Motior, M.R., Amano, T., Inoue, H., Matsumoto, Y., Shiraiwa, T., 2011. *Nitrogen uptake and recovery from N fertilizer and legume crops in wetland rice measured by 15N and non-isotope techniques*. J. Plant Nutr., 34(3): 402-426. doi: 10.1080/01904167.2011.536881

Mukherjee, D., 2015. *Integrated nutrient management practices for enhancing blackgram (Vigan mungo L. Hepper) production under mid hill situation in North Eastern Himalaya*. J. Food Legume, 28(1): 83-85.

Nasiri, M., Niknejad, Y., Pirdeshti, H., Barari Tari, D., Nasiri, S., 2008. *Growth, yield and yield traits of rice varieties in rotation with clover, potato, canola and cabbage in north of Iran*. Asian J. Plant Sci., 7(5): 495-499. doi: 10.3923/ajps.2008.495.499

Rahman, M.M., Islam, A.M., Azirun, S.M., Boyce, A.N., 2014. *Tropical legume crop rotation and nitrogen fertilizer effects on agronomic and nitrogen efficiency of rice*. Sci. World J., 490841: 1-11. doi:10.1155/2014/490841

Ren, T., Li, H., Lu, J., Bu, R., Li, X., Cong, R., Luc, M., 2015. *Crop rotation-dependent yield responses to fertilization in winter oilseed rape (Brassica napus L.).* Crop. J., 3(5): 396-404.

Sharma, S., Panneerselvam, P., Castillo, R., Manohar, S., Raj, R., Ravi, V., Buresh, R.J., 2019. *Web-based tool for calculating field-specific nutrient management for rice in India*. Nutr. Cycl. Agroecosyst., 113: 21-33. doi:10.1007/s10705-018-9959-x

Sidlauskas, G., and Bernotas, S., 2003. *Some factors affecting seed yield of spring oilseed rape (Brassica napus L.).* Agron Res., 1: 229-243.

Silva, J.V., Reidsma, P., Velasco, M.L., Laborte, A.G., van Ittersuma, M.K., 2018. *Intensification of rice-based farming systems in Central Luzon, Philippines: Constraints at field, farm and regional levels*. Agric. Syst.,165(C): 55-70. doi:10.1016/j.agsy.2018.05.008.

Singh, Y., Humphreys, E., Kukal, S.S., Singh, B., Kaur, A., Thaman, S., Prashar, A., Yadav, S., Timsina, J., Dhillon, S.S., Kaur, N., Smith, D.J., Gajri, P.R., 2009. *Crop performance in permanent raised bed rice-wheat cropping systems in Punjab, India*. Field Crops Res., 110(1): 1-20. doi: 10.1016/j.fcr.2008.06.009

Singh, Y., Singh, B., Timsina, J., 2004. *Crop residue management for nutrient cycling and improving soil productivity in rice-based cropping systems in the tropics*. Adv. Agron., 85: 269-407.

Tabrizi, A.A., Noormohammadi, G., Mobasser, H.R., 2015. *Effects of different cropping systems on fertility of paddy soil*. Iranian J. Crop Ecophysiol., 9(2): 191-202.

Thuy, N.H., Shan, Y., Singh, B., Wang, K., Cai, Z., Singh, Y., Buresh, R.J., 2008. *Nitrogen supply in rice-based cropping systems as affected by crop residue management*. Soil Sci. Soc. Am. J., 72: 514-523.

Tilman, D., Balzer, C., Hill, J., Befort, B.L., 2011. *Global food demand and the sustainable intensification of agriculture*. PNAS, 108: 20260-20264.

Urriola, J., and Rathore, K.S., 2015. *Overexpression of a glutamine synthetize gene affects growth and development in sorghum*. Transgenic Res., 24: 397-407. doi:10.1007/s11248-014-9852-6

Wichern, F., Eberhardt, E., Mayer, J., Joergensen, R.G., Muller, T., 2008. *Nitrogen rhizodeposition in agricultural crops: methods, estimates and future prospects*. Soil Biol. Biochem., 40(1): 30-48. doi:10.1016/j.soilbio.2007.08.010

Yadvinder-Singh, B.S., Ladha, J.K., Khind, C.S., Gupta, R.K., Meelu, O.P., Pasuquin, E., 2004. *Long-term effects of organic inputs on yield and soil fertility in the rice–wheat rotation*. Soil Sci. Soc. Am. J., 68(3): 845-853. doi:10.2136/sssaj2004.8450

Yamada, T., Katsuta, M., Sugiura, M., Terashima, Y., Matsuoka, M., Sugimoto, A., Ando, S., 2010. *Dry matter productivity of high biomass sugarcane in upland and paddy fields in the Kanto Region of Japan*. Jpn. Agric. Res. QTR., 44(3): 269-276. doi:10.6090/jarq.44.269

Yasumoto, S., Matsuzaki, M., Hirokane, H., Okada, K., 2010. *Glucosinolate content in rapeseed in relation to suppression of subsequent crop*. Plant Prod. Sci., 13(2): 150-155. doi:10.1626/pps.13.150

Yousaf, M., Li, J., Lu, J., Ren, T., Cong, R., Fahad, S., Li, X., 2017. *Effects of fertilization on crop production and nutrient-supplying capacity under rice-oilseed rape rotation system*. Sci. Rep., 7: 1270. doi:10.1038/s41598-017-01412-0

Zhao, X., Xie, Y.Z., Xiong, Z.Q., Yan, X.Y., Xing, G.X., Zhu, Z.L., 2009. *Nitrogen fate and environmental consequence in paddy soil under rice-wheat rotation in the Taihu Lake region, China.* Plant Soil., 319(1/2): 225-234.