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Original Article

Effect of Different N Fertilizer Combinations and Irrigation Regimes on Concentration, Uptake and Efficiency of Major Nutrients in *Plantago ovata*

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Abstract

In order to evaluate the response of major nutrients concentration, uptake and their efficiencies of isabgol (*Plantago ovata*) to N fertilizer combinations and irrigation regimes, a field experiment was conducted at the agricultural research farm of Shahrekord University, 2009. The experiment was arranged as split-plot, in randomized complete block design with three replications. The irrigation regimes (irrigation after 7, 14 and 21 days interval) were arranged as main plots and combination of different N fertilizers included control, urea fertilizer (UF), broiler litter (BL), UF+BL (3:1), UF+BL (1:1), UF+BL (1:3) as subplots. Results showed that the highest shoot dry weight and N uptake were achieved with 7 and 14 days irrigation regimes, respectively. There was no significant difference between 7 and 14 days irrigation regimes for shoot dry weight and N uptake. The greatest NAE, PAE and PPE were obtained with 14 days irrigation regimes. The highest shoot dry weight, N uptake, NAE, ANR and PAE were observed with UF+BL (1:1) as well as. UF+BL treatment led to increase NAE, ANR, PAE greater than solitary application of them. In conclusion, increase in N and P efficiency and dry matter associated with combined treatment (UF+Bl, 1:1) would help to minimize the use of synthetic mineral fertilizers and represents an environmentally and agronomically sound management strategy.

Key words: Broiler litter, Irrigation, Isabgol, Nutrient, Urea fertilizer

Introduction

Today, the nutrient deficiencies are increased as heavy withdrawal of nutrients by high-yielding varieties, intensive cropping systems and caused unbalanced insufficient use of organic and chemical fertilizers. The general tendency is that the total nutrients removed by crops are never replaced. Among the plant nutrients, the input efficiency of nitrogen through urea is lowest owing to the well-known losses of urea-N by various ways [1]. Manure is considered as the key to restoring the productivity of degraded soils as it supplies multiple nutrients, raises soil pH and improves soil organic matter (SOM), which in turn improves the physical and microbial properties of the soil [2]. Among organic manures, the nutrient content of poultry manures (PM) is the highest among all manures, and the use of PM as a soil strategy management for agricultural crops, provides appreciable quantities of all important plant nutrients [3]. Organic sources of nitrogen alone may not be able to provide sufficient nutrients in available form to plants and also cannot fulfill the immediate requirements of plants. To overcome this problem, integrated use of organic and inorganic sources of nutrients is recommended to maintain soil health, increased the efficiency of applied and natural nutrients and sustains required crop production [4]. The use of organic manure in combination with inorganic fertilizers to optimize nutrient availability to plants is a difficult task as organic materials have variable and complex chemical nature. This is a perquisite to understanding and acknowledgement of the chemical composition, particularly the nutrient content and carbon quality of organic materials and its interaction with inorganic nutrient sources.

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However there has been little information on the integrated effects of organic materials on nutrient management [5]. Numerous experiments have been conducted on the yields production from a given amount of inorganic fertilizer, an organic material, and their combination, and in many conditions, combinations of inorganic and organic fertilizer produced higher yields than inorganic and organic fertilizer alone. Soil water content during the growing season affects the response of plants to nitrogen fertilization [6]. There is a close relationship between uptake and translocation of nitrogen and plant growth stage under water deficiency. The rate of nutrients supply decreases in a dry soil, because the mobility of ions, water uptake, and new roots formation are affected adversely [7]. Therefore, this study was carried out to examine the effect of nitrogen fertilizer in combinations and irrigation regimes on the concentration, uptake and their efficiencies on isabgol.

Material and Methods

In order to evaluate the effect of irrigation regimes and integrated use of urea combined with broiler litter on the nutrients content, their uptake and efficiencies on the isabgol, a field experiment was conducted at the agricultural research farm of Shahrekord University, 2009.Thisexperimentwas arranged as a split-plot, in randomized complete block design with three replications. Irrigation regimes (after 7, 14 and 21 days regimes) and application of combined fertilizers (control, urea fertilizer (UF), broiler litter (BL), UF+BL (3:1), UF+BL (1:1), UF+BL (1:3)) were used as main-plot and sub-plot, respectively. Broiler litter was obtained from the animal husbandry Station of Shahrekord University. Poultry manure sample was analyzed for total nitrogen, phosphorus and potassium (Table 1). Composite soil sample at 0-30cm depth was collected from the experimental field and analyzed for soil characteristics (Table 1). The field was thoroughly prepared. Lay-out was carried out according to the experimental plan; with treatment plot size of 4 m x 2.5 m. Urea fertilizer and broiler litter at appropriate ratios were uniformly distributed in appropriate plots and thoroughly mixed with the soil. 50% urea was applied at the time of sowing and the remaining urea was added 30 days after sowing. Phosphorous fertilizer in form of triple superphosphate (30 kg ha^{-1}) was applied at the time of sowing. After thorough seed-bed preparation and fertilizer application, seeds of isabgol (*Plantago ovata* Forssk.) supplied by medicinal plant research, Jahad-e-Daneshgahi, Iran which cultivated in Iran as irrigated system, were planted by hand in 25 cm rows on the 23 May, 2009. At the harvest time, the area of one m^2 for each treatment plot was harvested for measurement of shoot dry weight.

Table 1 Characteristics of soil and broiler litter.

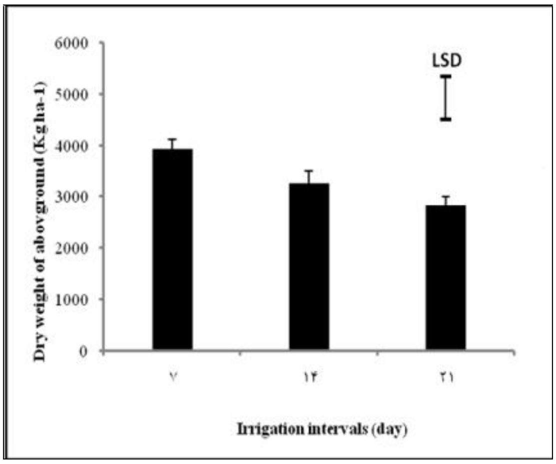
Broiler litter	Soil	Unit	Parameter
6.41	7.56	-	pH
12.1	0.48	(dS m^{-1})	EC
415	3.7	(g kg^{-1})	OC
30	0.3	(g kg^{-1})	N
20	7.5	(mg kg^{-1})	NH_4^+-N
13000	1.81	(mg kg^{-1})	K_2O
24000	25	(mg kg^{-1})	P_2O_5
13.83	12.33	-	C/N

The shoot dry weight of plant samples was determined after oven-drying at 80 ^{0}C for 24 h. Total N in the plant samples was determined in softly milled plant samples from each plot by the Dumas method [8]. Total phosphorus concentration of treatment was determined by ashing a 0.8-g subsample in a ceramic crucible at 500°C for 4 h followed by the dissolution of the ash in 1.0Ml of 6 M HCl for 1 h and then in an additional40 Ml of a double acid solution of 0.0125 M H_2SO_4 and 0.05 M HCl for an extra one hour, and filtering through Whatman no. 1 paper [9]. The P concentration of the filtrate was measured by emission spectroscopy.
The nitrogen and phosphorus data of samples were used for calculating the nitrogen and phosphorus efficiency parameters by the methods used by Abbasi *et al.* [4].
Agronomic efficiency of applied fertilizer N (NAE) = (Dry weight in plots with fertilizer – dry weight of control plots) / Applied N fertilizer.
Apparent fertilizer N recovery (ANR) = (N uptake by the fertilized plant – N in the control plants) / Applied N fertilizer ×100%.
Physiological efficiency of applied N (NPE) = (Dry weight in plots with fertilizer – dry weight of control plots) / (N uptake by the fertilized plant – N in the control plants).
P efficiency parameters were also calculated by the same methods used as N efficiency.
The data were analyzed statistically by the ANOVA procedure by the SAS statistical analysis system [10]. Significant means were tested by Least Significant Difference (LSD) at P< 0.05.

Results

Aboveground dry weight

Shoot dry weight of isabgol plant decreased 27% with increasing irrigation regimes from 7 to 21 days (Fig. 1). The highest shoot dry weight achieved with 7 days irrigation regimes. There was no significant difference between 7 and 14 days irrigation regimes.



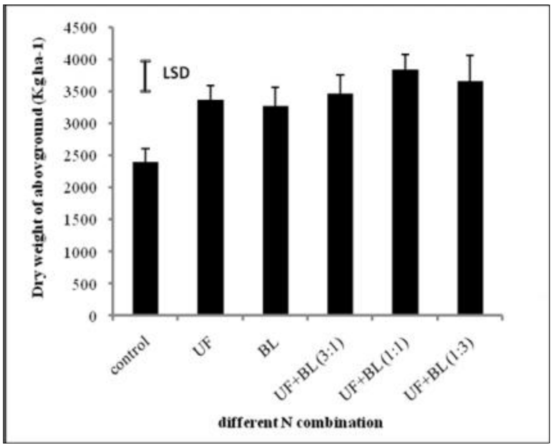


Fig. 1 Isabgol dry weight as influenced by irrigation regimes and fertilizer combinations. Bars show SE values. UF= urea fertilizer, BL= broiler litter.

The maximum shoot dry weight was obtained at UF+BL (1:1) treatment. This treatment increased the shoot dry weight by 60 and 14% more than control and 100% urea fertilizer treatments, respectively (Fig. 1).

Nutrient concentration and uptake

Concentration of N and P and were not significantly affected by irrigation regimes (Table 2). Nitrogen uptake was significantly affected by irrigation regimes ($P \leq 0.05$), but phosphorous uptake was not significantly affected by irrigation regimes (Table 2). 21 days irrigation regime reduced uptake of nitrogen by 38% rather than 7 days irrigation regime (Table 3).

N fertilizer combination treatment showed significant effect on the N and P concentration. Concentration and uptake of N and P for checked plot was significantly lower than fertilizer treatments. The highest N and P concentration were recorded at UF+BL (1:1) and UF+BL (1:3), respectively. N fertilizer combination caused significant effect on N and P uptake of aboveground. The highest N uptake was observed by UF+BL (1:1). This treatment increased nitrogen uptake by 31 and 33% and 2.4 times greater than single application of BL and UF and control treatment, respectively (Table 3). N fertilizer treatments thoroughly increased P concentration and its uptake more significantly than control. Besides control treatment, other treatments had no significant difference in terms of phosphorous uptake. the highest phosphorous uptake was obtained with UF+BL (1:3) (Table 3). This treatment increased phosphorous uptake 29% and 6 times greater than UF and control treatment, respectively.

Table 2 Analysis of variance (mean square) of irrigation regime and fertilizer combination effects on concentration and uptake of nitrogen and phosphorus of isabgol.

	Nitrogen		Phosphorus		N:P ratio
S.O.V.	concentration	uptake	concentration	uptake	
Replication	24.4 ns	1898 *	0.86 ns	102.2 *	3.8 ns
Irrigation (I)	39.8 ns	2863 *	0.12 ns	47.2 ns	10.4 ns
Error a	22.7	630	0.74	24.4	10.5
Fertilizer (F)	34.1*	1657 *	8.46 *	136.4 *	154.9 *
I × F	4.3 ns	176 ns	0.28 ns	7.3 ns	12.7 ns
Error b	7.3	112	0.36	6.8	6.4

ns, not significant.

* Significant at 0.05 probability level

Table 3 Effect of different N fertilizer combinations and irrigation regimes on concentration and uptake of nitrogen, concentration and uptake of phosphorus, and N:P ratio of isabgol aboveground.

Treatment	Nitrogen	Phosphorus		N:P ratio	
	concentration ($kg\ ha^{-1}$)	uptake ($g\ kg^{-1}$)	concentration ($kg\ ha^{-1}$)	uptake ($g\ kg^{-1}$)	-
Irrigation regimes					
I_1	16.41 a	64.97 a	2.80 a	11.91 a	8.1 a
I_2	16.53 a	54.80 ab	2.90 a	10.23 a	6.9 a
I_3	13.90 a	39.90 b	2.74 a	8.03 a	5.8 a
Fertilizer combination					
Control	12.14 c	28.87 c	0.88 c	2.19 c	15.6 a
UF	15.14 b	51.88b	3.01 b	10.30 b	5.2 b
BL	16.14 ab	52.93 b	3.29 ab	10.80 ab	5.0 b
UF+BL (3:1)	15.90 ab	55.14 b	3.04 ab	10.57 b	5.6 b
UF+BL (1:1)	18.02 a	69.33 a	3.05 ab	11.7 ab	6.6 b
UF+BL (1:3)	16.32 ab	61.20 ab	3.60 a	13.3 a	6.4 b

Means followed in each columns within each treatment with the same letter are not significantly different according to LSD (P<0.05). I_1, I_2 and I_3 = irrigation regimes 7, 14 and 21 days, respectively; UF= urea fertilizer, BL= broiler litter.

Table 4 Analysis of variance (mean square) of irrigation regime and fertilizer combination effects on nitrogen and phosphorus efficiencies of isabgol

	Nitrogen efficiency			Phosphorus efficiency		
S.O.V.	NAE	NPE	ANR	PAE	PPE	APR
Replication	219 ns	62.52 ns	0.084 ns	610 ns	581 ns	0.069 ns
Irrigation (I)	1853 *	1547 ns	0.569 ns	5147 *	21363 *	0.066 ns
Error a	379	680	0.339	1054	2294	0.038
Fertilizer (F)	191 *	213 ns	0.188 *	531*	6663 *	0.014 *
I × F	106 ns	240 ns	0.064 ns	296 ns	2998 ns	0.007 ns
Error b	77	308	0.045	214	2571	0.007

ns, not significant.
* Significant at 0.05 probability level

N fertilizer combination treatment showed significant effect on the N and P concentration. Concentration and uptake of N and P for checked plot was significantly lower than fertilizer treatments. The highest N and P concentration were recorded at UF+BL (1:1) and UF+BL (1:3), respectively. N fertilizer combination caused significant effect on N and P uptake of aboveground. The highest N uptake was observed by UF+BL (1:1). This treatment increased nitrogen uptake by 31 and 33% and 2.4 times greater than single application of BL and UF and control tretment, respectively (Table 3). N fertilizer treatments thoroughly increased P concentration and its uptake more significantly than control. Besides control treatment, other treatments had no significant difference in terms of phosphorous uptake. The highest phosphorous uptake was obtained with UF+BL (1:3) (Table 3). This treatment increased phosphorous uptake 29% and 6 times greater than UF and control treatment, respectively.

Nitrogen: Phosphorus ratio

N:P ratio was not affected significantly by the irrigation regimes (Table 2), however 7 days irrigation regime led to maximum N:P ratio (Table 3). 14, 7 and 21 days irrigation regime absorbed nitrogen 8.1, 6.9 and 5.8 times greater than phosphorous, respectively. N:P ratio was significantly affected by N fertilizer combination (Table 2). N fertilizer treatment produced less N:P ratio compared to the unamendment treatment (Table 3).

Nitrogen efficiency

Irrigation regime showed significant effect on the agronomic N efficiency (NAE), however apparent fertilizer N recovery (ANR) and physiological efficiency of applied N (NPE) were not significantly affected by irrigation regimes (Table 4). The highest NAE was obtained within 14 days irrigation regimes and no significant differences were observed within14 and 7 days irrigation regime. 21 days irrigation regime significantly reduced NAE (Fig. 2).

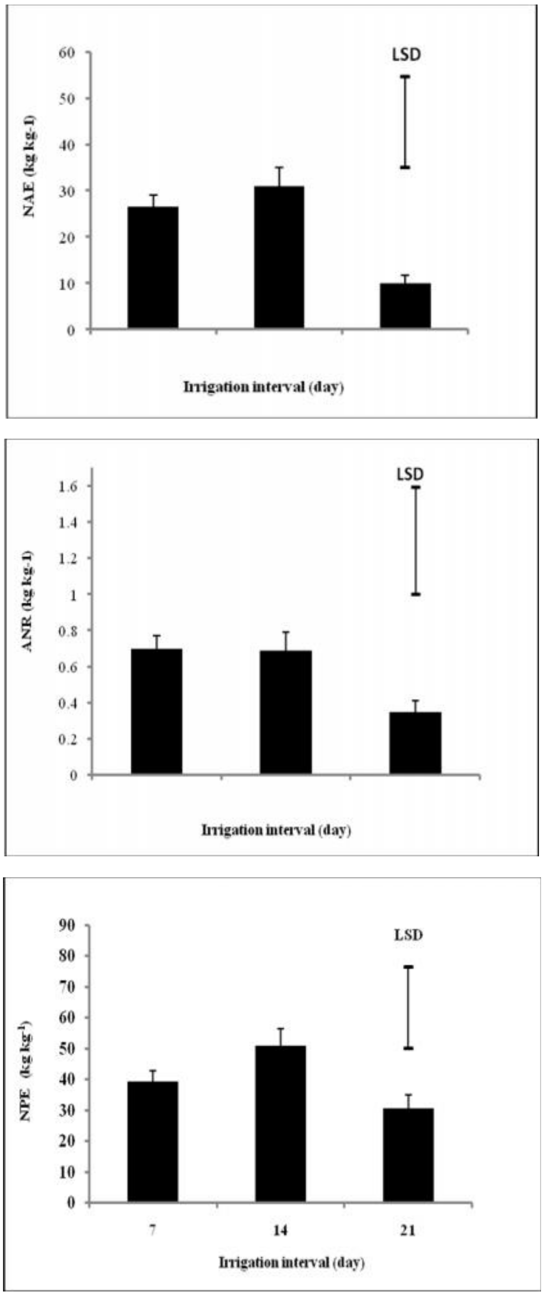


Fig. 2 Effect of irrigation regimes on Agronomic efficiency (NAE), Physiological efficiency (NPE) and Apparent fertilizer N recovery (ANR) of N applied to isabgol. Bars show SE values.

NAE and ANR were significantly affected by N fertilizer combination, but the effect of N fertilizer combination on NPE was not significant (Table 4). The maximum NAE and ANR were recorded at UF+BL (1:1) and did not show significant difference with other UF+BL treatments and UF+BL (1:3), respectively. Thoroughly, NAE and ANR as UF+BL treatments were greater than their single treatments (Fig. 3).

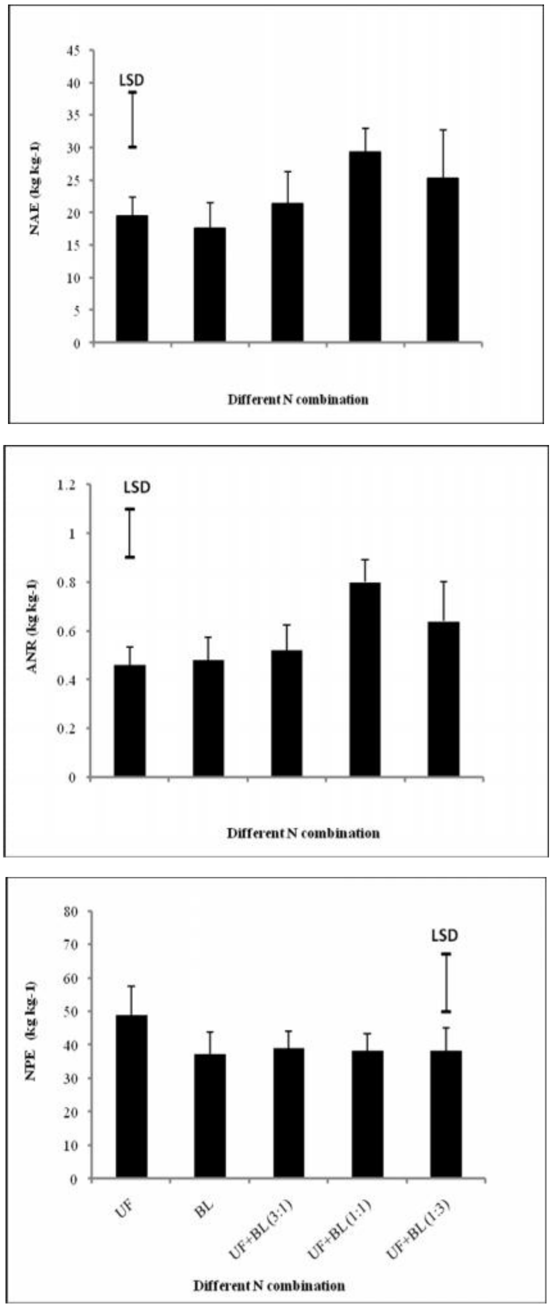


Fig. 3 Effect of different N combinations on Agronomic efficiency (NAE), Physiological efficiency (NPE) and Apparent fertilizer N recovery (ANR) of N applied to isabgol. Bars show SE values. UF= urea fertilizer, BL= broiler litter.

Phosphorus efficiency

Irrigation regimes showed a significant effect on the agronomic P efficiency (PAE) and physiological efficiency of applied P (PPE), however apparent fertilizer P recovery (APR) was not significantly affected by irrigation regimes (Table 4). The greatest PAE and PPE were obtained with 14 days irrigation regimes and no significant differences were recorded within 14 and 7 days irrigation regimes (Fig. 4).

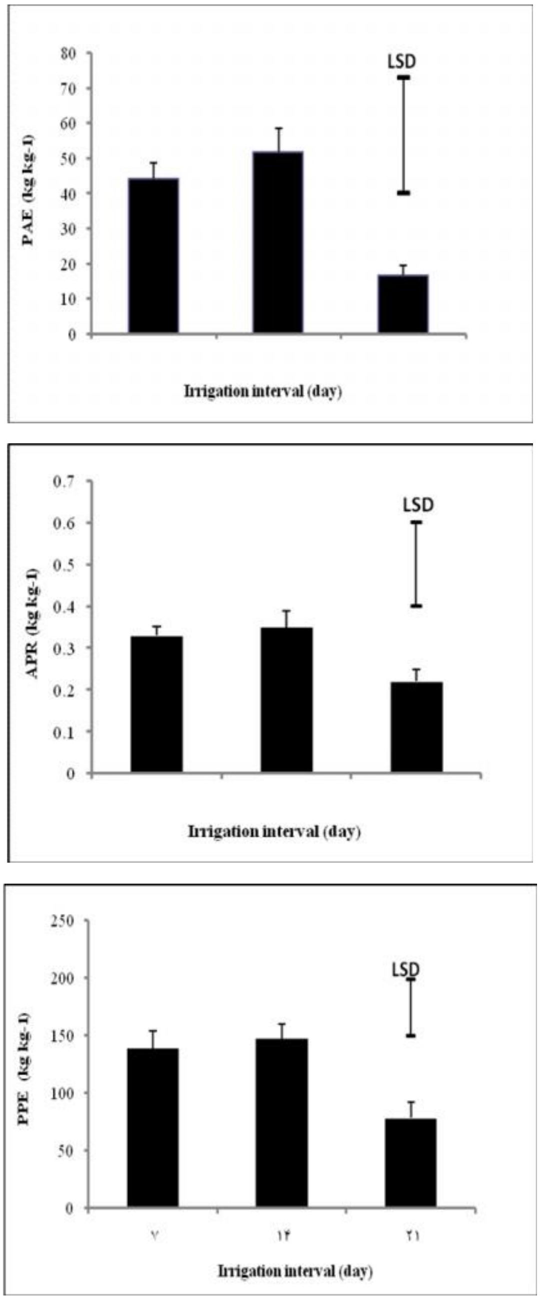


Fig. 4 Effect of irrigation regimes on Agronomic efficiency (PAE), Physiological efficiency (PPE) and Apparent fertilizer P recovery (APR) of P applied to isabgol. Bars show SE values.

UF+BL treatments led to increase PAE than single applications. The highest PAE and PPE were associated UF+BL (1:1) treatment (Fig. 5). The highest APR was observed by UF+BL (1:3) treatment that had not significant difference with treatments involved high ratio of broiler litter. UF+BL (1:3) treatment increased APR by 37 and 32% rather than UF and BL treatments, respectively (Fig. 5).

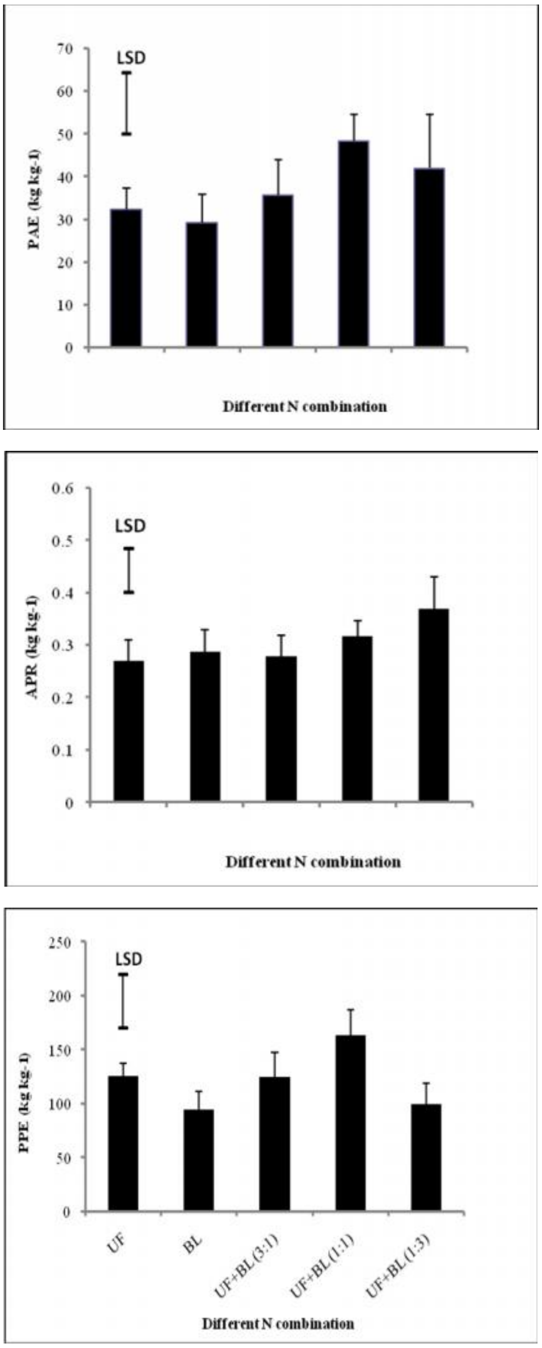


Fig. 5 Effect of different N combinations on Agronomic P efficiency (PAE), Physiological P efficiency (PPE) and Apparent fertilizer P recovery (APR) of P applied to isabgol. Bars show SE values. UF= urea fertilizer, BL= broiler litter.

Discussion

Shoot dry weight significantly decreased with enhancement of irrigation regime from within 7 to 21 days. Increase of shoot dry weight under optimal condition of irrigation (7 days irrigation) compared to non-optimal condition of irrigation, resulted in increase of leaf area, and consequently plants received more photosynthetic radiation and an increase of crop growth rate and relative growth rate [11]. Because of the mobility of ions, water uptake, and expansion of new roots the effects were contrary, and the rate of supply of nutrients decreased in a dry soil [12]. As a result, uptake of nitrogen and phosphorus decreased within 21 days irrigation regime. More reduction of nitrogen uptake rather than phosphorus would be due to more dependency to mass flow. It is possible that the fast growth rate of plant and more shoot dry weight under optimal condition of irrigation led to dilution of nutrients within the cells and tissue. Consequently, the N and P uptake within 7 days irrigation regime were not significantly increased compared to the 14 days irrigation regime. Ashraf *et al.* [13] reported that, nitrogen concentration of aboveground millet under water stress condition was more than control treatment. That were attributed to fast accumulation of free amino acid that did not converted into protein. They also suggested that slow growth rate of plant under water deficit stress possibility, prevents the dilution effect of nutrients within the cells and tissue. Frequent irrigation might increase leaching of soil solution nitrogen, and as a result a reduction of N:P ratio. Nitrogen uptake was greatly limited in the longer the irrigation regimes (21 days), due to the availability of drought condition in the soil. Consequently, N:P ratio within 21 days irrigation was decreased. Relative dry weight and NAE within 14 days irrigation were more than 7 days irrigation regime. The dry weight of control treatment (no fertilizer) within 7 and 14 days irrigation were 2805 and 1963 kg ha^{-1}, respectively. On the other hand, the effect of fertilizer treatments in the plots with moderate drought stress (14 days irrigation) was more than the plots with 7 days irrigation. Frequent irrigation (7 days irrigation regime) despite providing enough water for photosynthesis and crop growth also decreased nitrogen uptake due to leaching of nitrogen [14]. Decrease of nitrogen and phosphorus agronomic efficiency within 21 days irrigation is due to the reduction of photosynthesis under water stress condition. Frequent irrigation (7 days irrigation) would lead in leaching of nitrogen [14], and although water content would be desirable for plant growth, ANR with such treatment did not show any significant effect within 14 days irrigation. Doyle and Halford [15] also found that insufficient soil water resulted in reduction of nitrogen uptake efficiency. The phosphorous uptake was normally affected by 3 factors: root attributes, mycorrhiza attributes and soil properties which affect phosphorous solubility [16]. Phosphorous uptake decreased by 33% as an increase in irrigation regime from 14 to 21 days. Drought stress might inhibit P uptake by reducing P diffusion to roots through factors associated with water relations in the plant [17]. Reduction of relative uptake of phosphorous was more than reduction of relative uptake of nitrogen with the increased irrigation regime from 14 to 21 days (34 against 50). As a result, PPE, unlike NPE, did not show significant effect between 14 and 21 days irrigation regime.

The concentration and uptake of N and P increased significantly by fertilizer application. Aishwath *et al.* [18] also found significant increase with nitrogen and phosphorous uptake by application of 50 kg N ha^{-1} compared to control treatment (no fertilizer). The integrated urea and broiler litter treatments increased uptake of nitrogen and phosphorous more than their single applications. Other researchers also reported an increase of nitrogen and phosphorous uptake by FYM + urea treatments in comparison to the single application of urea [1,5,19]. Dwivedi *et al.* [1] obtained the highest rate of nitrogen uptake (69.3 kg ha^{-1}) and phosphorous uptake (23.8 3 kg ha^{-1}) with a utilization of 75% FYM by urea fertilizer. Indeed, the nutrient use efficiency of a crop is increased through a combined application of organic manure and mineral fertilizer [20]. The maximum concentration and uptake of phosphorous obtained by UF+BL treatments was due to the complementary effect of broiler litter with inorganic fertilizer, and therefore improved phosphorus extraction efficiency [21]. The application of combined animal manures, plant residues, and green manures with commercial phosphorous fertilizers may be beneficial to low-P soils to supplement P from manures and also to the increase in the efficiency of applied fertilizer P by chelating soil Ca, Fe, and Al by organic acids released upon decomposition of manures [22]. So, supplementary BL with UF may be an effective strategy in extracting P from soils and removing it from the field with harvested crop. Robbins *et al.* [23] stated that organic C in manure is more stable than organic C in whey and coats P adsorption and precipitation sites, allowing manure P to stay in solution longer. Eventually, release of organic acids during decomposition of manure can complex with Al and Fe, which are present in the soil, and therefore reduce fixation of applied P, which led to a greater P availability in the soil, and resulted information of phosphorus humic complexes that are easily assimilated by plants. These mechanisms may result in greater amounts of applied P in available forms to be used by plants [24]. Even though, single application of BL increased P uptake rather insignificantly, it still proved to be more significant than single application of UF. In checked plots, nitrogen of the soil solution have absorbed by crop but phosphorous of the soil, due to its fixation in the soil [25], isn't available for the crop, as a result, control treatment had the highest N:P ratio. The high correlation nitrogen uptake with phosphorous uptake (r=0.74**) showed nitrogen uptake by isabgol increase phosphorous uptake. Therefore, treatments with fertilizer (involved fertilizer) didn't show significant difference in terms of N:P ratio.

Generally, UF+BL treatments increased ANE and APE greater than their single application. Abbasi *et al.* [4] also found that ANE with integrated broiler litter and urea was significantly more than single application of broiler litter. UF+BL treatments resulted in an increase of ANR rather than their single application. UF treatment resulted in an increase of leaching nitrogen and its non-availability for the crop but, its integration with BL can synchronize nutrient release and crop demand that led to increase ANR or nitrogen uptake efficiency. This result was in agreement with Nyiraneza and Snapp [26]. They found that the integrated treatment (179 kg N ha^{-1} fertilizer + manure) consistently increased N uptake efficiency of potato by 20% compared to the unamended conventional management (224 kg N ha^{-1} fertilizer). Hirzel *et al.* [27] reported that apparent N recovery efficiency of silage maize was 20 and 33% by mineral N and 40, 26 and 43% by poultry manure. In this research, UF equivalent was calculated as 104. This suggested that the single application of BL had more N availability and utilization compared to the single application of urea fertilizer. Adeli *et al.* [28] reported that ANR in soybean was greater for broiler litter than commercial fertilizer. However, Russo *et al.* [29] reported non-significant reduction in N uptake efficiency with organic N fertilizer compared to mineral N fertilizer due to lack of synchronization between N availability and plant requirements in organic fertilizer applied in their research. A once application of phosphorous at the time of sowing resulted in fixation of a higher percentage of phosphorous in treatments involved chemical fertilizer due to calcareous condition of soil. In consequence, APR decreased in UF treatments while increased in BL. This is due to gradual release of phosphorous from broiler litter during nitrogen mineralization [30] and release of organic acids in the soil during manure decomposition and increase of phosphorous solubility [24] so, APR increased in such treatment. NPE decreased in treatments involved BL due to higher nitrogen uptake. Abbasi *et al.* [4] also reported a reduction of NPE with single application of broiler litter. PPE increased in treatments involved with high ratio of urea fertilizer (UF+BL (1:1), UF, UF+BL (3:1), respectively) due to lower uptake of phosphorous.

Conclusion

The results of this experiment showed that, 21 days irrigation regime is not recommended for isabgol due to significant reduction of nutrient uptake and nutrient agronomic efficiency (NAE and PAE). No significant difference between 7 and 14 days irrigation regime, illustrated that the 14 days irrigation regime not only conserves water resources in cropping system, but also makes nutrient uptake more efficient. In addition, the uptake of N and P in isabgol plant in UF+BL combination was greater than solitary application of these amendments. Therefore, increase in N and P efficiency and dry matter associated with combined treatment (UF+Bl, 1:1) would help to minimize the use of synthetic mineral fertilizers and represents an environmentally and agronomically sound management strategy.

Acknowledgements

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