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Comparative efficiency of barnyard grass and rice to nitrogen under transplanted condition

(Kecekapan rumput dibandingkan dengan pokok padi terhadap nitrogen dalam kawasan padi sistem cedung)

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Key words: barnyard grass, rice, nitrogen

Abstract

Barnyard grass [(*Echinochloa crus-galli* (L.) Beauv] is a major competitor of rice (*Oryza sativa* L.) in all growth factors, among which, nitrogen fertilizer uptake is an important one. To find out the relative efficiency of barnyard grass and rice against nitrogen fertilizer, a field experiment using fine rice Basmati-385 was conducted under irrigated transplanted condition in the semi-arid region of Punjab, Pakistan. Treatments consisted of different densities of barnyard grass at 0, 4, 8, 12 and 16 plants/m^2 while nitrogen fertilizer was at rates of 0, 60, 120 and 180 kg/ha applied at the time of transplanting and tillering stage.

Both the factors under study significantly affected the nitrogen uptake by barnyard grass and rice. Similarly, recovery efficiency of barnyard grass and rice, agronomic and physiological efficiencies and partial factor productivity of rice calculated at harvest of the crop were also significantly influenced by different barnyard grass densities and nitrogen levels. Barnyard grass performed better as compared to rice in absorbing nitrogen especially when the growing conditions were similar for both i.e. 16 plants of each in maximum nitrogen supply treatment (180 kg N/ha), showing better nitrogen uptake efficiency.

Recovery efficiency of barnyard grass was maximum at 120 kg N/ha with 16 barnyard grass/m^2, whereas the highest recovery efficiency of rice was observed at 60 kg N/ha and when there was no competition with barnyard grass. The highest physiological, agronomic and recovery efficiencies and partial factor productivity of rice were recorded at 60 kg N/ha with zero barnyard grass density.

Introduction

Rice production system in Pakistan strictly follows the puddling and transplanting method. Nitrogen fertilizer use efficiency is relatively low in irrigated rice because of rapid nitrogen losses from volatilisation and denitrification in the soil-flood water system (Vlek and Byrnes 1986; DeDatta and Buresh 1989). Despite the fact that newly evolved varieties respond very well to nitrogen fertilizer, the recovery to applied nitrogen is often very low. Recovery of nitrogen fertilizer applied to the rice crop averages 30 – 40% and seldom exceeds 60 – 65% even with the best agronomic practices. An uptake efficiency of 30 – 50% requires

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100–150 kg N/ha to obtain a yield of 6.0 t/ha (DeDatta et al. 1969). The rest is lost in one way or another (Crasswell and Vlek 1978). Inefficient utilisation of nitrogen contributes to greater use of energy resources, increased production costs and possible pollution of water by nutrients (Sharpe et al. 1988). Necessary measures are therefore essential to be adopted to increase the utilization efficiency of nitrogen through appropriate management techniques.

Weed infestation is one of the major constraints in good rice production even with a high-level of nitrogen application. Increased nitrogen level may compensate for inadequate weed control. On the contrary, increased nitrogen enhances weed growth and results in greater competition and low rice yields than when there is little or no fertilizer. Rice and weeds showed similar rate of nitrogen uptake at zero nitrogen and greater uptake by weeds at 150 kg N/ha (Ampong and DeDatta 1989). Thus at high fertilizer levels, weed competition is more critical than at low nitrogen levels.

Among the weeds of rice crop, *Echinochloa crus-galli* (L.) Beauv (barnyard grass) is the worst one. It accounts for 90% loss out of the total caused collectively by all weeds (Kwesi et al. 1991). Similar findings by Smith Jr. (1968) stated that even few barnyard grass plants/m^2 can reduce yield considerably. As the density of barnyard grass increases, corresponding decrease in rice yield occurs. Chisaka (1966) found a linear relationship in producing rice yield between barnyard grass and rice.

A study was therefore conducted to determine the competitive behaviour of rice crop growing in different densities of barnyard grass and nitrogen levels under transplanted condition.

Materials and methods

The experiment was conducted during 1998–1999 at the agronomic research area, University of Agriculture Faisalabad, which is situated at 31.25° N; 73.09° E with 184.8 m altitude. The soil is of the Lyallpur soil series (aridisol-fine-silty, mixed, hyperthermic Ustalfic, Haplarged in USDA classification and Haplic Yermosols in FAO classification). The experimental site had a pH of 7.85 and 7.90 and organic matter was at 0.70% and 0.71% during both years of study respectively.

Almost one-month-old seedlings were transplanted on well prepared (puddle + planked) soil in the first week of July at 25 cm x 25 cm hill spacing. Phosphorus and potassium at 0–60 kg/ha was applied during the final stages of field preparation. The experiment was designed as Randomised Complete Block Design with split plot treatment arrangement with four replications. The main plots consisted of 0, 60, 120 and 180 kg N/ha treatments applied in two equal splits i.e. $^1/_2$ at transplanting and remaining $^1/_2$ at tillering stage (30 days after transplanting). Subplot treatments were 0, 4, 8, 12 and 16 plants of barnyard grass obtained by broadcasting its pre-collected seeds.

The weed plants were removed manually soon after their emergence. The net plot size was 3 m x 2 m. Fine rice variety Basmati-385 was used as test crop. Weekly irrigation was supplied to the crop until maturity. Harvesting was done manually when evidence of physiological maturity appeared and panicles fully ripened containing about 22% moisture, determined by a moisture tester. The grain weight was adjusted to 14% moisture content.

Nitrogen content of these samples was determined by Kjeldahls method (Yoshida et al. 1976) and relating parameters were determined by the formula as presented by Mengal and Kirby (1987).

Nitrogen uptake

Nitrogen uptake by barnyard grass and rice (above ground) was calculated in kg/ha by the formula as follows:

N uptake by barnyard grass = % N in weed x weed dry wt.

N uptake by rice = % N in paddy x paddy yield + % nitrogen in straw x straw yield

Recovery efficiency (RE) of applied nitrogen

RE answers the question: How much of the N applied was recovered and taken up by the plant?

RE_N = kg N taken up/kg N applied

$RE_N = (UN_{+N} - UN_{0N})/FN$

Where UN_{+N} is the total plant N uptake measured in above ground biomass at physiological maturity (kg/ha) in plots that received applied N at the rate of FN (amount of fertilizer N applied) in kg/ha. UN_{0N} is the total N uptake without N addition.

Agronomic efficiency (AE) of applied nitrogen

AE answers the question: How much additional yield can be produced for each kg of N applied?

AE_N = kg grain yield increase/kg N applied

$AE_N = (GY_{+N} - GY_{0N})/FN$

Where GY_{+N} is the grain yield in a treatment with N application, GY_{0N} is the grain yield in a treatment without N application, and FN is the amount of fertilizer N applied (kg/ha).

Physiological efficiency (PE) of applied nitrogen

PE answers the question: How much additional yield can be produced for each additional kg of N uptake?

PE_N = kg grain yield increase per kg fertilizer N taken up

$PE_N = (GY_{+N} - GY_{0N})/UN_{+N} - UN_{0N})$

Where GY_{+N} is grain yield in a treatment with N application (kg/ha), GY_{0N} is grain yield in a treatment without N application, and UN is total N uptake (kg/ha) in two treatments.

Partial factor productivity (PFP) from applied nitrogen

PEP answers the question: How much yield can be produced for each kg of N applied?

PEP_N = kg grains/kg N applied

$PEP_N = GY_{+N}/FN$

Where GY_{+N} is the grain yield in a treatment with N application and FN is the amount of fertilizer N applied (kg/ha).

All the data were analysed by using the analysis of variance on MSTATC computer package (Anon. 1986). A combined analysis of two years data was performed. Duncan new multiple range test was used to separate the treatments. In case of significant interaction, only the interactive values were compared, otherwise a separate effect was discussed.

Results and discussion

It is apparent from the data depicted in *Tables 1–3* that various nitrogen levels and barnyard grass densities significantly influenced all the parameters under the study. The two variables interact significantly in the case of nitrogen uptake and recovery efficiency of barnyard grass and nitrogen uptake and partial factor productivity of rice while not significantly in the case of physiological efficiency, agronomic efficiency and recovery efficiency of rice.

The nitrogen uptake by barnyard grass increased significantly with successive increase in nitrogen application rates as well as barnyard grass densities. Maximum nitrogen uptake by weed was recorded in N_4D_5 (180 kg N/ha and 16 barnyard grass plants/m^2) followed by N_3D_5 (120 kg N/ha and 16 barnyard grass plants/m^2) treatment combination. Maximum uptake in N_4D_5 (180 kg N/ha and 16 barnyard grass plants/m^2) was due to the availability of maximum nitrogen and also due to the highest number of barnyard grass plants/m^2, which produced the maximum dry weight of the weed.

Table 1. Nitrogen uptake by rice and barnyard grass as affected by barnyard grass densities and nitrogen levels

Treatment		Nitrogen uptake (kg/ha)					
		Rice			Barnyard grass		
1	2	1998	1999	Mean	1998	1999	Mean
N_1D_1	(0 x 0)	81.08	88.74	84.91i	0.00	0.00	0.00n
N_1D_2	(0 x 4)	79.47	86.65	83.06i	12.60	11.51	12.05m
N_1D_3	(0 x 8)	75.94	82.17	79.06j	25.88	23.75	24.82i
N_1D_4	(0 x 12)	70.30	75.80	73.05k	33.81	33.36	33.57h
N_1D_5	(0 x 16)	63.52	68.15	65.84l	47.60	44.09	45.85e
N_2D_1	(60 x 0)	98.98	106.60	102.79f	0.00	0.00	0.00n
N_2D_2	(60 x 4)	97.17	103.65	100.41fg	18.24	16.48	17.36l
N_2D_3	(60 x 8)	90.18	99.08	94.63h	34.21	32.85	33.53h
N_2D_4	(60 x 12)	82.46	90.35	86.41i	45.95	45.25	45.60e
N_2D_5	(60 x 16)	72.02	80.38	76.20jk	60.24	56.94	58.59d
N_3D_1	(120 x 0)	116.83	122.73	119.78bc	0.00	0.00	0.00n
N_3D_2	(120 x 4)	113.75	120.51	117.03cd	20.12	19.19	19.66k
N_3D_3	(120 x 8)	107.53	108.95	108.24e	40.02	39.20	39.61g
N_3D_4	(120 x 12)	94.00	100.20	97.10gh	62.41	56.01	59.21d
N_3D_5	(120 x 16)	81.13	87.79	84.46i	78.20	73.92	76.06b
N_4D_1	(180 x 0)	123.90	130.60	127.25a	0.00	0.00	0.00n
N_4D_2	(180 x 4)	119.85	126.63	123.24b	21.90	21.32	21.61j
N_4D_3	(180 x 8)	111.24	119.38	115.31d	42.87	42.13	42.50f
N_4D_4	(180 x 12)	100.58	107.13	103.85f	63.34	62.24	62.79c
N_4D_5	(180 x 16)	83.17	88.05	85.61i	87.28	85.40	86.34a
C.V. (%)				3.63			4.57

1 = Treatment combinations; 2 = Nitrogen (kg/ha) x Barnyard grass (plants/m^2)
Means with different letters are significantly different (p = 0.05)

The decrease in uptake was noted with corresponding decrease in nitrogen levels as well as in barnyard grass densities. The maximum recovery efficiency of barnyard grass was observed in N_3D_5 (120 kg N/ha and 16 barnyard grass plants/m^2) followed by N_4D_5 (180 kg N/ha and 16 barnyard grass plants/m^2) and N_2D_5 (60 kg N/ha and 16 barnyard grass plants/m^2) treatment combinations. It suggested that at 120 kg N/ha barnyard grass performed very well. The nitrogen was neither too little nor surplus for this weed, because at this particular dose sufficient quantity of nitrogen was available without any severe threat to losses in the form of leaching and volatilisation.

Sharma and Gupta (1992) revealed that nitrogen uptake by weeds increased as applied nitrogen increased. Highest nitrogen uptake by rice was observed in N_4D_1 (180 kg N/ha without barnyard grass plant) treatment combination in which maximum nitrogen was applied in the absence of any competition imposed by barnyard grass, while treatment combinations N_3D_1 (120 kg N/ha without barnyard grass plant) and N_4D_2 (180 kg N/ha and 4 barnyard grass plants/m^2) followed this treatment. Rice plants take up the least amount of nitrogen under highest barnyard grass density (16 plants/m^2) at zero nitrogen (N_1D_5). Reddy and Hukkaeri (1980) stated that the more fertilizers applied to modern rice, weeds, if left unchecked, use the greater amount of nutrients. The maximum nitrogen uptake in N_4D_1 (180 kg N/ha without barnyard grass plant) was most probably due to the maximum supply of nitrogen and was efficiently taken up in the absence of weed competition.

Table 2. Partial factor productivity of rice and recovery efficiency of barnyard grass as affected by barnyard grass densities and nitrogen levels

Treatment		Partial factor productivity (Rice)			Recovery Efficiency (Barnyard grass)		
1	2	1998	1999	Mean	1998	1999	Mean
N_1D_1	(0 x 0)	0.00	0.00	0.00	0.00	0.00	0.00
N_1D_2	(0 x 4)	0.00	0.00	0.00	0.00	0.00	0.00
N_1D_3	(0 x 8)	0.00	0.00	0.00	0.00	0.00	0.00
N_1D_4	(0 x 12)	0.00	0.00	0.00	0.00	0.00	0.00
N_1D_5	(0 x 16)	0.00	0.00	0.00	0.00	0.00	0.00
N_2D_1	(60 x 0)	63.52	65.00	64.26a	0.000	0.000	0.000i
N_2D_2	(60 x 4)	62.90	64.30	63.60a	0.093	0.065	0.079g
N_2D_3	(60 x 8)	59.17	61.85	60.51b	0.137	0.150	0.144e
N_2D_4	(60 x 12)	55.00	56.65	55.83c	0.198	0.195	0.196c
N_2D_5	(60 x 16)	46.80	48.75	47.77d	0.223	0.215	0.219b
N_3D_1	(120 x 0)	36.78	37.20	36.99e	0.000	0.000	0.000i
N_3D_2	(120 x 4)	36.20	36.83	36.51e	0.060	0.050	0.055h
N_3D_3	(120 x 8)	33.35	33.50	33.42f	0.115	0.130	0.123f
N_3D_4	(120 x 12)	30.07	30.73	30.40g	0.237	0.190	0.214bc
N_3D_5	(120 x 16)	25.68	26.47	26.07h	0.255	0.247	0.251a
N_4D_1	(180 x 0)	26.07	26.45	26.26h	0.000	0.000	0.000i
N_4D_2	(180 x 4)	25.25	25.85	25.55hi	0.053	0.042	0.047h
N_4D_3	(180 x 8)	23.60	24.30	23.95i	0.093	0.100	0.096g
N_4D_4	(180 x 12)	21.40	21.65	21.52j	0.165	0.160	0.162d
N_4D_5	(180 x 16)	16.87	17.17	17.02k	0.223	0.230	0.226b
C.V. (%)				5.11			14.89

1 = Treatment combinations; 2 = Nitrogen (kg/ha) x Barnyard grass (plants/m^2)
Means with different letters are significantly different (p = 0.05)

Table 3. Physiological, agronomic and recovery efficiency of rice as affected by barnyard grass densities and nitrogen levels

	Physiological Efficiency (Rice)			Agronomic Efficiency (Rice)			Recovery Efficiency (Rice)		
Nitrogen (kg/ha)	1998	1999	Mean	1998	1999	Mean	1998	1999	Mean
N_1 = 0	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.00
N_2 = 60	41.40	39.71	40.56a	9.93	10.80	10.37a	0.233	0.259	0.246a
N_3 = 120	35.53	37.20	36.36b	8.72	8.62	8.67b	0.237	0.240	0.238a
N_4 = 180	35.75	35.11	35.43b	6.86	6.87	6.86c	0.188	0.191	0.189b
Barnyard grass (plants/m^2)									
D_1 = 0	30.92	31.33	31.13a	11.51	10.81	11.16a	0.276	0.269	0.273a
D_2 = 4	30.14	30.16	30.15ab	11.01	10.44	10.72a	0.273	0.262	0.268a
D_3 = 8	28.65	28.79	28.72ab	8.54	9.33	8.94b	0.232	0.249	0.240b
D_4 = 12	27.74	26.63	27.19b	7.14	8.10	7.62c	0.185	0.213	0.199c
D_5 = 16	23.39	23.11	23.25c	4.32	5.14	4.73d	0.131	0.156	0.143d
C.V. (%)			24.39			15.31			13.96

Interaction (Nitrogen x Density) = Not significant
Means with different letters are significantly different (p = 0.05)

Rafey et al. (1989) reported that by increasing nitrogen rates, the uptake of nitrogen by rice also increased. As the rice-barnyard grass interference increased, the competition for nitrogen uptake was also increased and so less nitrogen was taken up by rice as compared to barnyard grass. This concludes that nitrogen uptake by barnyard grass was more at higher nitrogen levels i.e. 180 kg/ha. It is very important to note that with the same densities of barnyard grass and rice at higher nitrogen level (N_4D_5) i.e. 16 plants/m^2 each of rice and barnyard grass, the barnyard grass take up more nitrogen (86.34 kg/ha) as compared to rice (85.61 kg/ha), although the rice plants were one month old with well-developed root systems, as compared to barnyard grass seeds which just started to germinate (transplanting time).

Rice plants efficiently recovered the N in treatments where 60 kg /ha (N_2) was applied. That was at par to 120 kg N /ha (N_3) followed by 180 kg N/ha (N_4) applications, whereas rice growing without any competition i.e. D_1 showed the maximum recovery efficiency that was significantly not different when compared with four plants of barnyard grass (D_2). An almost similar trend was observed in the case of agronomic and physiological efficiency. The highest agronomic and physiological efficiencies were observed in 60 kg N/ha and zero barnyard grass density. All these nitrogen use efficiencies under study linearly decrease with increasing amount of nitrogen fertilizer and barnyard grass plants per unit area. Maximum efficiency in 60 kg N/ha might be due to little wastage in the form of leaching and volatilisation.

Similarly, the highest efficiencies of rice without any competition with barnyard grass might be supported by the fact that as the competition increased, the nitrogen uptake by barnyard grass increased and hence ultimately N use efficiency was affected.

Similar findings were reported by Singh and Sharma (1993) who stated that nitrogen recovery and nitrogen use efficiency are maximum at 60 kg N/ha. The nitrogen use efficiency response illustrates the linear trend by nitrogen rates and barnyard grass densities.

Maximum partial factor productivity was observed in N_2D_1 (60 kg N/ha without barnyard grass plant) treatment combination that was significantly at par as compared to N_2D_2 (60 kg N/ha and 4 barnyard grass plants) interaction. While the lowest partial factor productivity was noted in maximum nitrogen application treatment with maximum number of barnyard grass plants. This is again supported by the fact that at 60 kg N/ha there might be very low loss of nitrogen in the form of volatilisation leaching and absorption by barnyard grass. While in N_4D_5 (180 kg N/ha and 16 barnyard grass plants/m^2) treatment, there was the maximum competition with barnyard grass as well as sufficient quantity of nitrogen is available for leaching and volatilisation.

Conclusion

Determination of the uptake and subsequent use of nitrogen by rice and barnyard grass suggests that barnyard grass is a very efficient plant because it took up more nitrogen as compared to rice in similar growth conditions. Increased nitrogen levels could not compensate inadequate barnyard grass control. Moreover, nitrogen use efficiency in rice decreased with the corresponding increase in nitrogen doses. Therefore for successful rice production and maximizing the benefits from the applied nitrogen, an optimum quantity of nitrogen fertilizer should be applied without any competition with barnyard grass. This is very essential to avoid losses in the form of leaching, volatilisation and absorption by barnyard grass.

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Abstrak

Rumput sambau [(*Echinochloa crus-galli* (L.) Beauv] ialah saingan utama padi (*Oryza sativa* L.) dalam semua faktor pertumbuhan, dan antaranya pengambilan baja nitrogen adalah yang penting. Untuk mengetahui kecekapan relatif rumput sambau dan pokok padi terhadap baja nitrogen, satu percubaan ladang menggunakan beras Basmati-385 telah dikendalikan dalam sistem penanaman cedung berpengairan di wilayah separa kering di Punjab, Pakistan. Perlakuan termasuklah kepadatan berbeza bagi rumput sambau iaitu 0, 4, 8, 12 dan 16 pokok/m^2 manakala kadar baja nitrogen ialah 0, 60, 120 dan 180 kg/ha digunakan pada waktu cedung atau mengubah dan peringkat beranak.

Kedua-dua faktor yang dikaji nyata sekali memberi kesan terhadap pengambilan nitrogen oleh rumput sambau dan pokok padi. Begitu juga, kecekapan pemulihan rumput sambau dan pokok padi, kecekapan agronomi dan fisiologi, dan faktor separa produktiviti pokok padi yang dikira pada waktu penuaian adalah dipengaruhi dengan nyata oleh pelbagai kepadatan rumput sambau dan kadar nitrogen. Prestasi kecekapan pengambilan nitrogen oleh pokok sambau adalah lebih baik daripada pokok padi dalam menyerap nitrogen terutamanya apabila keadaan pertumbuhan adalah sama iaitu 16 pokok dalam perlakuan kadar nitrogen yang maksimum (180 kg N/ha).

Kecekapan pemulihan rumput sambau adalah paling tinggi pada kadar 120 kg N/ha dengan 16 batang rumput/m^2, manakala kecekapan pemulihan pokok padi telah diperhatikan pada kadar 60 kg N/ha dan apabila tiada saingan dengan rumput sambau. Kepadatan pemulihan yang tertinggi bagi fisiologi, agronomi dan faktor separa produktiviti pokok padi telah direkodkan pada kadar 60 kg N/ha ketumpatan rumput sambau sifar.

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