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Nitrogen indices of wheat sown with happy seeder with skipped row techniques as affected by split nitrogen application

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ABSTRACT

A field experiment was conducted to study the effects of skip row planting techniques and N application time on different nitrogen indices of happy seeder sown wheat in rice residues with two seasons (2011–12 and 2012–13). The experiment was laid out in split plot design and had 3 planting patterns and 6 nitrogen application treatments. In the planting patterns, M2 had higher values of agronomic use efficiency, nitrogen utilization efficiency (NUtE), nitrogen use efficiency, nitrogen uptake efficiency. While nitrogen harvest index (NHI) and nitrogen balance index (NBI) were higher in M1 followed by M3. Results showed that agronomic use efficiency, nitrogen utilization efficiency (NUtE), nitrogen harvest index (NHI), nitrogen balance index, and grain protein content (GPC) in wheat were significantly affected by split application of nitrogen over control treatment. Linear relationship of grain yield and grain protein content revealed that when wheat sown with skip row planting technique and N applied in three splits, resulted in higher N indices.

Keywords : Nitrogen uptake efficiency, skip row planting and time of N application

Wheat is one of the most important cereal crop and staple food globally. Wheat provides more protein than any other cereal crops but, the global challenge for wheat nutrition is to increase grain yield while maintaining its protein. Wheat yield and end-use quality depend upon the environment, genotype, and their interactions. High levels of N supply results in a higher protein content, but increased efficiency of utilization is realized when concentration in the kernels increases, and grain yield remains stable (Ortiz-Monasterio *et al.,* 1997). Proper N application timing and rates are critical for meeting crop needs, and indicate considerable opportunities for improving N use efficiency (NUE). NUE, grain yield produced per unit of N supply, is a complex trait comprising N uptake efficiency (NU_pE), and N utilization efficiency (NU_tE). NU_pE reflects the ability of the plants in obtaining N, while NUtE reflects the efficiency with which the crop utilizes N in the plant for the synthesis of grain yield. Tran and Tremblay (2000) reported that wheat NU_pE was lower in the early applications at planting and tillering than application in the later crop growth stage. The amount of economic yield, therefore, increased by increasing NU_pE and NU_tE through efficient N application that decreases N losses from the soil-plant system (Muurinen, 2007).

Nitrogen-use efficiency (NUE) can be improved by developing fertiliser management strategies based on a better synchronisation between the supply of N and its requirement by a given crop. Many studies have shown that split applications of N fertiliser result in higher rates of plant recovery, and higher grain yields than under single applications. However, the proportions of the split should be determined locally, with due consideration of the initial soil fertility. Nitrogen use efficiency depends on the nitrification rate of the soil, the form of N applied, and the growth stage of the plant. Farmers must apply N at the ideal time, and use the fertilization method, which will optimize efficiency.

MATERIALS AND METHODS

The experiment was conducted for two seasons (2011–2012 and 2012–2013) at the Punjab Agricultural University (PAU) farm at Ludhiana (30°56'N, 75°52'E, 247m ASL), Punjab, India. The region is characterized by a sub-tropical and semi-arid climate with a hot dry summer (March–June),wet monsoon season (late June–mid September) and a cool, dry winter (October–February).Average annual rainfall is 734mm (constituting 44% of pan evaporation) of which about 80% is received during the monsoon. The Meteorological data were collected from the weather station on the PAU farm, located about 0.5 km from the experimental site. Data collected included daily maximum and minimum temperatures, pan evaporation and sunshine hours and rainfall (Fig. 1 and 2).The experimental soil was low in nitrogen (228.6-215.6 kg $ha^{-1}$from 0-15 and 15-30 cm) and medium in P and K (18.7-16.9 kg $ha^{-1}$and 188.7-183.5 kg $ha^{-1}$from 0-15 and 15-30 cm, repectively) and low in organic carbon (0.31-0.29%).

The experiment was laid out in a split plot design with 3 planting pattern (M_{1-3} rows at 20 cm inter-row spacing and 40 cm space between two sets of rows, M_2-2 rows at 20 cm inter-row spacing and 40 cm space between two sets of rows, M_3-Normal sowing at 20cm row spacing) as the main plots and 6 nitrogen application treatments(T_1-Control:; T_2- 1/2 dose of recommended

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N basal+ 1/2 dose of recommended N with 1st irrigation; T_3- No basal+ 1/2 dose of recommended N with 1st irrigation + 1/2 dose of recommended N with 2nd irrigation ; T_4- 3/4 dose of recommended N basal+ 1/4 dose of recommended N with 1st irrigation; T_5- 1/4 dose of recommended N basal+ 3/4 dose of recommended N with 1st irrigation; T_6- 1/4 dose of recommended N basal+ 1/4 dose of recommended N with 1st irrigation + 1/2 dose of recommended N with 2nd irrigation) in sub-plots. The experiment was replicated three times.

The following N-efficiency indices were computed using following formulas.

Nitrogen use efficiency was computed by the formula .

$$\text{Nitrogen use efficiency} = \frac{\text{Grain yield kg ha}^{-1}}{\text{Total N supply (kg ha}^{-1})}$$

Nitrogen supply was calculated as N applied as fertilizer plus total nitrogen uptake in control plots.

Nitrogen Agronomic use efficiency

$$\text{N Agronomic use efficiency} = \frac{\text{(Grain yield in fertilized plot - grain yield in control plot) kg ha}^{-1}}{\text{Total N fertilizer applied (kg ha}^{-1})}$$

Nitrogen Apparent recovery fraction (ARE)

$$\text{N Apparent Recovery fraction} = \frac{\text{(N uptake in fertilized plot - N uptake in control plot) kg ha}^{-1}}{\text{Total N fertilizer applied (kg ha}^{-1})}$$

N utilization efficiency (UTE)

$$\text{N utilization efficiency (kg grains per kg total N uptake)} = \frac{\text{Grain yield kg ha}^{-1}}{\text{Total N uptake by crop (kg ha}^{-1})}$$

Agro-physiological efficiency (APE)

$$\text{Agro-physiological efficiency} = \frac{\text{(Grain yield in fertilized plot - grain yield in control plot) kg ha}^{-1}}{\text{N uptake in fertilized plot- N uptake in unfertilized plot}}$$

Nitrogen uptake efficiency (NU_pE)

$$\text{Nitrogen uptake efficiency} = \frac{\text{Total plant N uptake kg ha}^{-1}}{\text{Total N fertilizer applied (kg ha}^{-1})}$$

Nitrogen balance index (NBI)

$$\text{Nitrgen balance index} = \frac{\text{N uptake by grains}}{\text{Total N fertilizer applied}}$$

Nitrogen harvest index (NHI)

$$\text{Nitrgen harvest index} = \frac{\text{N uptake by grains}}{\text{Total N uptake by crop}}$$

Nitrogen efficiency terminology follows: Huggins and Pan (1993), Sowers *et al.* (1994), and Delogu *et al.* (1998).

Data were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedures of the Statistical Analysis System followed by Tukey,s Test at $P<0.05$.

RESULTS AND DISCUSSION

Yield -grain protein relations

Skip row technique has dominant effect on grain yield. The method M1 gave significantly better yield over M2 and at par with M3 in both years. That may be due to the border effect that M1 method received more PAR interception, and higher value of leaf area index over M3 method. No doubt above said parameters were also higher in M2 method but plant population per hectare is reduced by 33 per cent over M3 and 8 per cent over M1 method. Similarly, it was observed that the spilt application of N influences the yield and yield contributing characters over the two years as a whole. Highest grain yields was obtained when nitrogen was applied ¼ at the time of sowing, ¼ dose with 1st irrigation (*i.e.* CRI stage) and ½ dose with 2nd irrigation (*i.e*. initiation of stem elongation stage), which was recorded the highest grain yield 56.8 and 54.08 q ha^{-1} during 2011-12 and 2012-13, respectively. The lower grain yield of 36.5 and 34.89 q ha^{-1} recorded under the control treatment. Protein value was higher in M_1 as compare to M_2 and M_3. In the nitrogen treatment combinations highest protein value is obtained in T_6 and there was positive relation between grain yield and grain protein content (Fig.3 and 4). Our results are in line with the findings of Geleto *et al.* (1995) who reported that fertilizer application increased wheat productivity over control. T_6 treatment has higher grain yield over other treatments *i.e.* T_1, T_2, T_3, T_4, and T_5, where we applied N fertilizer in three splits. Split applications of N might have decreased the losses of N and better synchronization with plant demand resulting in increased in wheat biomass. Application of N had increased the uptake of N, which might be attributed to higher N availability of the crop. Alcoz *et al.* (1993), Sowers *et al.* (1994) and Lo´pez-Bellido *et al.* (2005) also report an increase in yield when N was applied in two splits specially at CRI and start of stem elongation stage Split application of N had increased the availability of N for crop and thus more uptakes was recorded from plots where N was applied in split application

Agronomic use efficiency (AUE)

It represents the efficiency with which plant uses each additional unit of N acquired, and quantifies the plant responses to applied N fertilizer. Agronomic use efficiency was significantly highest in M_2 than M_1 and M_3. This might be due to lesser difference in fertilizer treatments, and control. While nitrogen application time treatments has non-significant difference in AUE with each other. T6 treatment had highest AUE followed by T_5, T_2, T_3, and T_4.This showed that there was higher N content in the grains proportionately the N amount applied. Lowest value observed in T_4,where, we applied $3/4^{th}$ of recommended N dose at the time of sowing and remaining $1/4^{th}$ after first irrigation, which resulted in lesser yield due to availability of N only for small period of growth cycle. Agronomic efficiency was directly correlated with grain yield.

Agro-physiological efficiency

It represents the ability of a plant to transform N acquired from fertilizer into economic yield (grain). Data recorded showed that plants were more efficient to transferred applied N fertilizer to economic part (yield) in M2 method as compared to the M_1 and M_3. However, the difference was non-significant. All the split time application treatments had non-significant effect on this efficiency. Highest value of agro-physiological efficiency was observed in T_2 as compare to the other treatments , this might be due to the higher biological yield in this treatment, which resulted in more N uptake . There was positive relation of total N uptake with the grain yield (Fig. 5)

Apparent recovery efficiency

It is also referred as crop recovery efficiency of applied nitrogen. The perusal of the results revealed that the M_2 had significantly higher (59.50 and 54.50 %) apparent recovery value over M_1(51.77 and 46.47 %) and M_3(54.35 and 39.41 %) in both years. Nitrogen application time also affected apparent recovery efficiency .T_6 treatment had significantly higher value over T_2, T_3, T_4 and T_5; this showed the direct correlation of this efficiency with the grain yield.

N utilization efficiency (NUtE)

It reflects the efficiency with which crop utilize N in the plants for synthesis of grain yield. As the difference in grain yield and harvest index was not so wide , so under the entire planting patterns, the differences in NUtE were negligible or non-existent; which indicated that there was equal utilization of N in all the treatments. Under N application treatments, it was observed that control treatment (zero N) gave 12.40 and 16.03 per cent higher value of NUtE than the mean value for timing and splitting treatments using 125kg N ha^{-1} This confirms the major contribution of high levels of residual soil N to grain yield, due to the accumulation of N fertilizer over time. Our results are in agreement with findings of Mercedes *et al.*(1993) who reported that split fertilizer N application improved N uptake in wheat. Control plots had efficiently utilized the available inherent N and thereby increased the NU_tE compared to fertilized plots. The T_4 treatment where ¾ of recommended fertilizer applied at the time of sowing and ½ dose after 1^{st} irrigation, had significantly lower NUE over T_2, T_3, T_5, and T_6 treatments. This might be attributed to the greater N losses as previously reported by many researchers. Rahman *et al.* (2002) reported that N use efficiency of wheat was the maximum when nitrogen fertilizer was applied in three splits rather than two splits or applied as all basal in no-till condition.

Nitrogen harvest index (NHI)

The N harvest index, defined as N in grain to total N uptake, is an important consideration in cereals. NHI reflects the grain protein content and thus the grain nutritional quality. Montemurro *et al.* (2006) suggested that grain N uptake was positively correlated with yield, protein content and total N uptake and a significant positive correlation found in NHI, yield and total N uptake. Results obtained in this experiment showed that wheat grain yield was affected by planting pattern. In M_1 highest yield was obtained. The yield difference in M_2 and M_3 planting method was non-significant lead to non-significant increase in NHI. Highest value observed

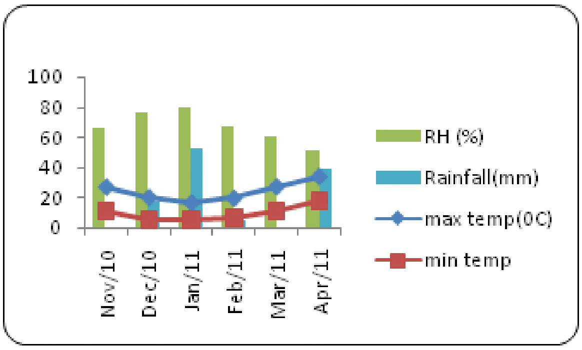

Fig. 1: Weather data 2011-12

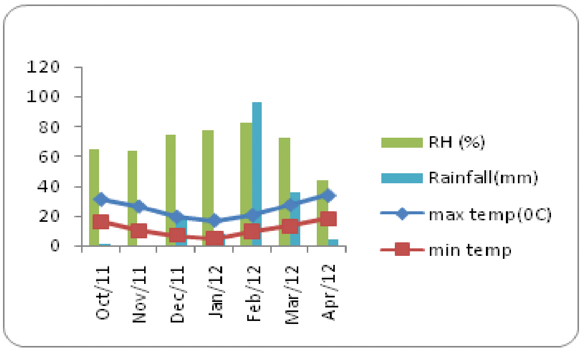

Fig. 2: Weather data 2012-13

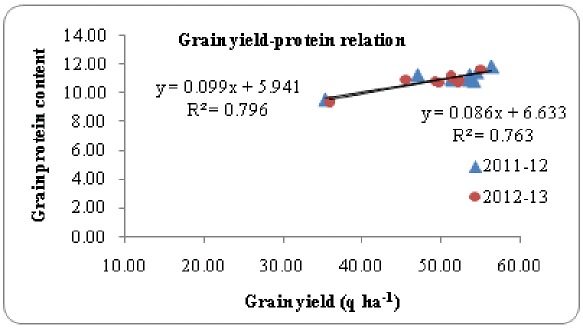

Fig. 3: Grain yield- protein relation under different planting methods and time of nitrogen application

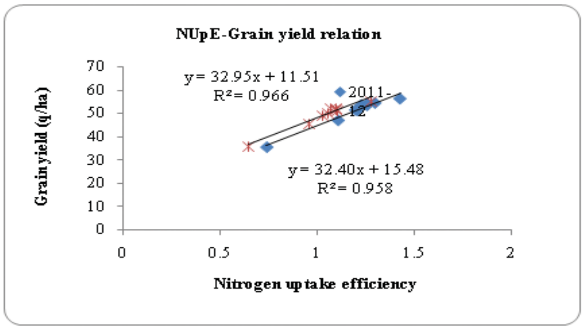

Fig. 4: Relationship of nitrogen uptake efficiency with grain yield in 2011-12 and 2012-13

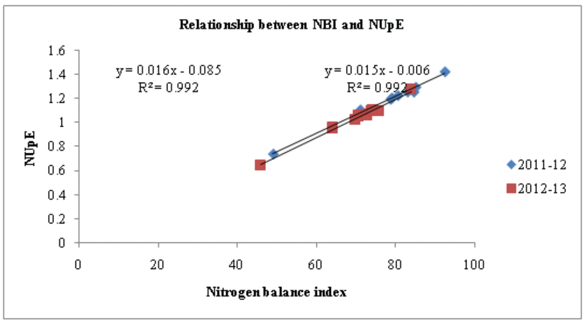

Fig. 5: Relationship of nitrogen uptake efficiency with nitrogen balance index in 2011-12 and 2012-13

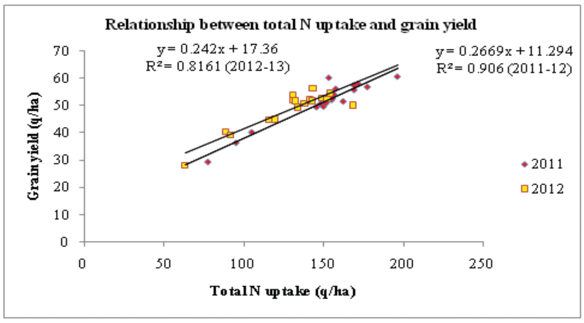

Fig. 6: Relationship of total nitrogen uptake with grain yield in 2011-12 and 2012-13

in M_1 which was statistically significant from M_2 and M_3. No differences for NHI were observed when N was applied as full dose or in split doses.

Nitrogen balance index (NBI)

The NBI represents the ratio of N removal via grain harvest to N fertilizer inputs. NBI was varied significantly with planting methods. Highest NBI observed in M_1 followed by M_2 and M_3 in both years. As it was explained earlier that there was linear relationship between grain yield and protein content. High protein means more N uptake by grains, which ultimately increased the NBI. Highest NBI observed in T_6. During first year T_6 significantly higher from all other treatments while in the second year this treatment at par with T_2, T_3,T_4,T_5 and significant over control, T_1. Nitrogen balance index had positive relation with NU_pE (Fig. 6)

Table 1: Agronomic use efficiency, apparent recovery efficiency and agro-physiological efficiency under different planting methods and time of nitrogen application

Treatments	Agronomic use efficiency (kg grain kg^{-1} N applied)		Apparent recovery efficiency (kg N uptake fertilizer^{-1} N applied)		Agro-physiological efficiency (kg grain kg^{-1} uptake)	
	2011-12	**2012-13**	**2011-12**	**2012-13**	**2011-12**	**2012-13**
Planting methods						
M_1	13.33	12.74	51.77	46.47	26.14	26.51
M_2	16.87	16.90	59.50	54.45	27.95	28.85
M_3	14.35	9.19	54.35	39.41	26.21	21.46
SEm (±)	**2.46**	**3.55**	**4.70**	**7.69**	**2.58**	**4.06**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Time of N application						
T_1	-	-	-	-	-	-
T_2	14.65	13.10	49.45	42.17	29.63	27.50
T_3	14.55	12.95	53.13	44.95	27.22	25.98
T_4	12.90	10.65	47.09	37.76	26.27	26.56
T_5	15.33	12.69	57.12	46.41	26.37	24.70
T_6	16.83	15.35	69.24	62.59	24.35	23.29
SEm (±)	**1.49**	**1.53**	**4.12**	**3.55**	**1.20**	**2.04**
LSD (0.05)	**NS**	**NS**	**12.03**	**10.34**	**NS**	**NS**
Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 2: Nitrogen indices under different planting methods and time of nitrogen application

Treatments	Nitrogen balance index (NBI) (%)		Nitrogen harvest index (NHI) (%)		Nitrogen utilization efficiency (NU_tE) (kg grain kg^{-1} N uptake)		Nitrogen uptake efficiency(NU_pE) (Kg N uptake kg^{-1} N supplied)		Nitrogen use efficiency(NUE) (Kg N uptake kg^{-1} N supplied)	
	1st yr	**2nd yr**	**1st yr**	**2nd yr**	**1st yr**	**2nd yr**	**1st yr**	**2nd yr**	**1st yr**	**2nd yr**
Planting methods										
M_1	84.47	75.55	66.60	68.49	34.61	38.27	1.26	1.07	24.93	23.27
M_2	70.95	63.97	63.69	66.75	34.13	38.68	1.11	0.96	21.62	22.14
M_3	78.69	70.54	64.92	66.85	34.24	38.18	1.21	1.09	23.64	24.16
SEm (±)	**1.69**	**1.66**	**0.46**	**0.64**	**0.33**	**0.34**	**0.01**	**0.01**	**0.26**	**0.19**
LSD (0.05)	**6.64**	**6.54**	**1.81**	**NS**	**NS**	**NS**	**0.09**	**0.07**	**2.90**	**2.19**
Time of N application										
T_1	48.96	45.84	65.96	69.90	38.28	44.30	0.74	0.65	16.21	17.41
T_2	80.47	72.69	65.27	67.55	34.84	38.86	1.23	1.07	24.71	25.36
T_3	82.89	73.98	65.30	67.04	33.83	37.40	1.26	1.10	24.65	24.95
T_4	78.63	69.75	64.87	67.77	34.06	38.36	1.20	1.03	23.70	23.87
T_5	84.97	74.06	64.81	66.55	33.30	36.79	1.30	1.11	25.10	24.84
T_6	92.32	83.81	64.21	65.36	31.66	34.56	1.43	1.27	25.96	26.72
SEm (±)	**2.98**	**3.53**	**1.14**	**1.4**	**0.58**	**0.55**	**0.02**	**0.03**	**0.33**	**0.74**
LSD (0.05)	**8.62**	**10.20**	**NS**	**NS**	**1.70**	**1.60**	**0.11**	**0.10**	**2.03**	**2.80**
Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Nitrogen uptake efficiency

NU_pE reflects the efficiency of the crop in obtaining N from soil. Results showed that wheat NUpE was affected by planting patterns and split application of nitrogen. NUpE in planting pattern M_1 and M_2 in both years had significantly higher (11.90, 8.2 % and 10.3, 11.9 %) NU_pE over M_2. Lee *et al.* (2004) indicated that NU_pE was positively correlated with plant dry matter, leaf area index and leaf nitrogen content. Results showed that there was positive correlation between NU_pE and grain yield of wheat (Fig. 5). Among N application time treatments, T_6 was significantly higher from all N application time treatments. There was negligible difference in T_2, T_3, T_4 and T_5; were significantly higher over T_1.

Planting method had non-significant effect on NUE and Agro-physiological efficiency, while Agronomic use efficiency, apparent recovery efficiency was higher in M_2 though the difference with M1 was non-significant. Highest NHI and NBI were observed in M_1 followed by M_3 and M_2.Split application of N had increased the wheat productivity and N indices. Thus, for improved wheat productivity and efficient N utilization and uptakes the splits application of N at later stage of the crop should be practiced in agro-climatic conditions of Punjab.

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