Genotypic effects on yield, N uptake, NUTE and NHI of spring wheat

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Abstract

Ten spring wheat (*Triticum aestivum* L.) genotypes (4 Indian and 6 Mexican) were evaluated at 180 and 300 k?g N/ha application at CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo), near Ciudad Obregon, Sonora, Mexico during 1997-1998 and 1998-1999 for their yield potential, N concentration in grain and straw and their relationships. From pooled analysis, effect of N rates on biomass, yield and yield attributing characters was non-significant whereas genotypic effects on the above mentioned characters as well as on grain N concentration, uptake, nitrogen harvest index and utilization efficiency were significant. From combined analysis across years, grain yield and harvest index (HI) ranged from 7.81 t/ha (Pavon 76) to 9.13 t/ha (Baviacora 92) and from 39.5 % (Pastor) to 45.1 % (Baviacora 92), respectively. The range of grain N concentration, uptake and nitrogen utilization efficiency (NUE) was from 1.99 % (Baviacora 92) to 2.23 % (Rayon 89), from 147.6 kg/ha (Pastor) to 169.5 kg/ha (UP 2338), and from 29.8 kg grain/kg N uptake (Pavon 76) to 35.6 kg grain/kg N uptake (Baviacora 92), respectively. The grain yield correlated positively with HI (r = 0.66), NHI (r = 0.62), grain N uptake (r = 0.77) and negatively with N concentration in grain (r = -0.68) and straw (r = -0.64). The correlation between HI and NHI was highly positive (r = 0.89), which suggested that enhancing these two indices could lead to higher grain yield and protein content. Therefore, these two indices should be given more emphasis for enhancing yield potential of spring wheat genotypes.

Media summary

Yield of spring wheat varieties could be further enhanced by increasing harvest index and nitrogen harvest index under high fertility irrigated conditions.

Key words:

Grain yield, harvest index, nitrogen harvest index, spring wheat genotype

Introduction

The advent of semi-dwarf wheat had increased the yield potential during mid 1960s. The high yielding, semi-dwarf, photo insensitive, wheat varieties released after ‘Green Revolution’ were selected to respond to high nitrogen (N) input (Earl and Ausubel, 1983). Genetic selection was for high harvest index (HI) under medium to high N rates, whereas, HI and nitrogen harvest index (NHI) in wheat might respond differently to N fertilizer depending upon the amount and timing of its application. Efficiency in dry matter partitioning or HI is defined as the ratio of grain yield to total biomass at maturity (Donald, 1962). Efficiency in N partitioning or N harvest index is defined as the ratio of N uptake by grain to total N uptake at maturity (Austin and Jones, 1975).

Generally, an inverse relationship between grain yield and grain N concentration has been reported in bread wheat (Cox et al., 1985; Stoddard and Marshall, 1990). However, the degree of this relationship varies with soil fertility, water availability and other environmental factors. It is also essential to maximize grain yield and N concentration in grain with optimum N use. The amount of N applied depends upon the yield level of the crop and apparent N recovery. Hobbs *et al*. (1997) envisage that a wheat crop yielding 7.0 t/ha might require 330, 254 and 206 kg N/ha provided it shows 50, 65, and 80 % apparent N recovery, respectively. They assumed that wheat crop without N can yield up to 2 t/ha only. Nitrogen use efficiency can be defined as the product of uptake efficiency (total N uptake/applied N through fertilizer) and utilization efficiency (yield/total N uptake). At low N rates, uptake efficiency is dominant as compared to utilization efficiency whereas utilization efficiency is relatively more important than uptake efficiency at high N rates (Ortiz Monasterio et al., 1997). In the past more emphasis was placed on grain yield than on the concentration of N in grain. Therefore, our objective was to evaluate the important Indian and Mexican spring wheat genotypes, released during the last quarter of the 20 th century, for yield potential, N concentration in grain and straw and their relationship.

Methods

An experiment was carried out at CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo), near Ciudad Obregon, Sonora, Mexico (lat. 27.33?N, long.109.09?W and 38 m above sea level) in 1997-98 and 1998-99. The soil was a coarse sandy clay, mixed montmorillonitic typic calciorthid, low in NO_3^- N (29.5 ppm) and NH_4^+ N (6.1 ppm), medium in available P (7.7 ppm) and organic matter (0.89 %), high in K (557 ppm) and alkaline (pH = 8.0) in nature. The minimum temperature in November, December, January and March was lower (about 1 ?C) in 1998-99 than in 1997-98.

The study consists of two N levels (180 and 300 kg/ha) in main plots and 10 historical spring wheat genotypes (6 from Mexico namely Baviacora 92, Seri 82, Pastor, Pavon 76, Rayon 89, Bacanora 88 and 4 from India namely PBW 343, UP 2338, WH 542 and HD 2329 in sub plots, which were grown in a split plot design with three replications. The crop was sown during the last week of November by plot drill into dry soil followed by irrigation to give about 300 viable seeds/m^2 in rows, 20 cm apart. At sowing time, 100 kg N/ha was applied as urea and 46 kg/ha phosphorus as single super phosphate. Potash was not applied due to inherent high content of potassium (557 ppm) in soil (0-15 cm depth). Top dressing of 200 kg N/ha through urea was done at DC 31 stage (Zadoks et al., 1974) followed by irrigation. Herbicides, like Topik (Clodinafop-propargyl) @ 250 ml/ha and Brominal (Bromixinil @ 1.5 l/ha) + Harmony (Thiofensulfuron @ 25 g /ha) were applied by knapsack sprayer at the two leaves weed stage for control of grassy and non-grassy weeds, respectively.

The net plot of 3.6 m^2, excluding border rows and ends of the plot, was harvested manually 7-10 days after physiological maturity. All yield and yield attributing characters were obtained using methods described by Bell and Fischer (1994). At physiological maturity a sub sample of 50 tillers per plot was taken and dried for 48 hours at 70 ^{0}C. Thereafter these were threshed and straw + chaff samples were collected. Grain collected from these tillers was weighed and added to the yield of the plot. Afterwards the grain and straw + chaff samples were dried and ground separately. Nitrogen in grain and straw was determined by a Kjeldahl method (Humphries, 1956). The data of the experiment were analyzed on pooled basis using MSTATC. Mean of the two years data was used for a correlation study of important parameters.

Results

From across years analysis, the effect of N rates on biomass, yield and other component characters was at par (data not given) whereas varietal differences were significant (Table 1). Variety Baviacora 92 was significantly taller (103 cm) and HD 2329 was significantly shorter (84.4 cm) than other varieties. Generally, genotypes under study took 132 to 136 days between emergence to maturity except HD 2329, which was about one week early. Mexican variety Baviacora 92 produced maximum biomass (17.82 t/ha), grain yield (9.13 t/ha) and thousand grain weight (48.2 g) despite lowest spikes/m^2 (370). Seri 82 recorded the highest HI (45.9 %) and grains/spike (46.7) whereas Pastor recorded the lowest HI (39.5 %) and HD 2329 the lowest grains/spike (31) compared to other varieties. Varietal differences in grain yield were in agreement with many workers (Stapper and Fischer, 1990). At the same place, in a historical set of varieties, Sayre et al. (1997) reported that average yield increased linearly from 66.8 q/ha (Pitic 62) to 84.8 q/ha (Bacanora 88). Generally varieties possessing higher spikes/m^2 showed lower thousand grain weight and vice versa.

The effect of N rates on N concentration and uptake in grain and NHI was non-significant whereas straw N concentration, uptake and NUE were significantly higher at 300 kg N/ha than at 180 kg N/ha application (data not given). From mean of two years (Table 2), the range of grain N concentration, uptake and total uptake was, respectively, from 1.99 % (Baviacora 92) to 2.23 % (Rayon 89), from 147.6 kg/ha (Pastor) to 169 .5 kg/ha (UP 2338), and from 223 kg/ha (Pastor) to 241 kg/ha (Pavon 76). Similarly range of straw N concentration and uptake was from 0.58 % (Bacanora 88) to 0.79 % (Pavon 76) and from 53.6 kg/ha (PBW 343) to 80.4 kg/ha (Pavon 76), respectively. This lead to maximum NUE 35.6 kg grain/kg N uptake by Baviacora 92 and minimum 29.8 kg grain/kg N uptake by Pavon 76. Highest N harvest index was determined by PBW 343 (74.9 %) and lowest by Pavon 76 (65.5 %). Similar findings were also reported by various workers (Halloran and Lee, 1979 and Dhugga and Waines, 1989).

Table 1: Genotypic differences in plant height, biomass, yield and its attributing characters in pooled analysis across years.

Parameters	Plant height (cm)	Biomass (kg/ha)	Yield (kg/ha)	HI (%)	1000 grain weight (g)	Spikes/m^2	Grains/spike
Genotypes							
PBW 343	94.4	16117	8281	45.2	47.0	408	38.2
UP 2338	90.0	17554	8837	44.3	45.1	407	42.4
Baviacora 92	103.3	17815	9134	45.1	48.2	370	45.4
Seri 82	91.9	16683	8708	45.9	42.0	392	46.7
Pastor	100.9	17687	7924	39.5	44.8	460	34.3
WH 542	86.7	17093	8572	44.1	35.4	481	44.4
HD 2329	84.4	15549	7971	45.1	44.7	510	31.0
Pavon 76	99.2	17191	7808	40.0	38.7	541	33.2
Rayon 89	96.9	17746	8082	40.2	36.2	522	37.9
Bacanora 88	86.8	17766	8815	43.8	36.4	490	43.8
LSD (P=0.05)	1.7	727	302	1.5	1.2	31	2.7

Table 2: Varietal differences in N concentration in grain and straw, uptake, NUE and NHI in pooled analysis across years.

Parameters	N Concentration (%)		N Uptake (kg/ha)			NUE (kg grain/ kg N uptake)	NHI (%)
Genotypes	Grain	Straw	Grain	Straw	Total		
PBW 343	2.19	0.60	159.6	53.6	213	34.3	74.9
UP 2338	2.18	0.66	169.5	64.3	233	33.3	72.5
Baviacora 92	1.99	0.66	160.3	65.1	225	35.6	71.1
Seri 82	2.14	0.64	163.9	57.3	221	34.7	74.2
Pastor	2.12	0.71	147.6	76.8	224	31.2	65.9
WH 542	2.07	0.63	157.8	59.5	217	35.2	72.6
HD 2329	2.20	0.71	154.3	60.4	215	32.7	71.9
Pavon 76	2.19	0.79	152.5	80.4	233	29.8	65.5
Rayon 89	2.23	0.66	158.3	70.6	229	31.0	69.3
Bacanora 88	2.08	0.58	161.9	57.9	220	35.3	73.5
LSD (P=0.05)	0.04	0.05	6.94	6.93	9.8	1.24	2.6

Grain yield correlated positively with HI (0.66), NHI (0.62), grain N uptake (0.77) and negatively with N concentration in grain (-0.68), straw (-0.64) and straw N uptake (-0.54). The correlation between HI and NHI was highly positive (0.89) whereas between HI and straw N uptake was highly negative (-0.89). As shown by Sinclair (1998), NHI is directly dependent on HI and therefore a positive association between HI and NHI is generally expected. Positive correlation between HI and NHI has been reported in durum wheat (Desai and Bhatia, 1978) and in bread wheat (Loffler and Busch, 1982). Nitrogen harvest index also showed a positive association with N uptake by grain (0.72) and a negative trend with straw N concentration (-0.83) and straw N uptake (-0.98), as expected. In order to gain more information on the relationship between HI and NHI, mean NHI over two N rates and years was regressed on mean HI. The slope (b= 0.67) of the regression line, 1 % increase in HI was accompanied by 0.67 % increase in NHI, suggesting that improvement in NHI has lagged behind HI in wheat breeding programmes. Recently, Ehdaie and Waines (2001) also observed that 1 % increase in HI was accompanied by 0.84 % increase in NHI, corroborating our findings. Biomass at maturity didn't correlate well with any of the important parameters. Therefore, grain yield and protein could be maximized with selection of varieties having high HI and NHI.

Conclusion

Study of important Indian and Mexican spring wheat varieties at high N level (180 and 300 kg/ha) resulted in significant differences in yield, N concentration, uptake, NUE and NHI. The positive correlation of grain yield with HI (r=0.66), NHI (r=0.62), grain N uptake (r-0.77) and negative correlation with grain (r=-0.68) and straw (r=-0.64) N concentration exhibited the possibility of further increases in yield under high input condition. HI and NHI correlated positively (r=0.89), which suggested that enhancing these two indices could lead to higher grain yield.

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