Performance and gene effects for wheat yield under inoculation of arbuscular mycorrhiza fungi and *Azotobacter chroococcum*

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ABSTRACT

The present investigation was conducted to know the impact of bio-inoculants in low input field conditions on the magnitude and direction of gene effects and mean performance of some morphological and productivity traits in three wheat cultivars WH 147 (medium mineral input), WH 533 (drought tolerant), Raj 3077 (drought tolerant) and six generations namely P_1, P_2, F_1, F_2, BC_1 and BC_2 of three crosses i.e. WH 147 × WH 533, WH 533 × Raj 3077 and WH 147 × Raj 3077. The experiment was conducted in randomised block design with three replications and three treatments i.e. control (C, without inoculation), inoculation with arbuscular mycorrhiza fungi (AMF, *Glomus fasciculatum*), and AMF + *Azotobacter chroococcum* (Azc). Mineral fertilizer (80 kg N/ha + 40 kg P/ha + 18 kg $ZnSO_4$/ha) was applied in all the three treatments. The application of bio-inoculants, AMF and AMF + Azc had a positive effect on plant height, peduncle length, grain yield, biological yield and harvest index in various populations of all the crosses. However, in some of the generations the impact of bio-inoculants was insignificant. The joint scaling test revealed that additive-dominance gene effects were mainly operative in governing expression of peduncle length, tillers per plant, plant height, grains/spike, grain yield and all traits except days to flowering and harvest index in crosses WH 147 × WH 533 and WH 533 × Raj 3077. The application of bioinoculants influenced gene effects for days to flowering, days to maturity, flag leaf area, spike length, grains/spike, 1000 grain weight and harvest index where complex genetic interactions were changed to simple additive-dominance gene effects in the cross WH 147 × Raj 3077. Likewise, additive-dominance gene effects were altered and digenic interactions exhibited for days to maturity, flag leaf area in WH 147 × WH 533 and days to flowering, plant height, flag leaf area in WH 533 × Raj 3077. Flag leaf area and plant height were governed by additive gene effects while for days to maturity and 1000-grain weight both additive and dominance gene effect were important. Duplicate epistasis was important in all the three crosses for days to flowering and harvest index and in the cross WH 147 × Raj 3077 for grain weight grains per spike and flag leaf area.

Keywords: wheat; *Azotobacter chroococcum*; arbuscular mycorrhiza fungi; gene effects

Integrated nutrient management strategies involving chemical fertilizers and bio-fertilizers have been suggested to enhance the sustainability of crop production (Manske et al. 1998). The bio-inoculants help the expansion of root systems and better seed germination and plant growth (Manske et al. 1995). Inoculation with arbuscular mycorrhiza fungi (AMF) has been found to increase the availability of phosphorous and other nutrients in crop plants because of its symbiotic associations with plant roots, colonizing cortical tissues and extending hyphae into the rhizosphere (Hetrick et al. 1996). Similarly, the inoculation of *Azotobacter chroococcum* (Azc) also complements wheat-AMF interaction due to its nitrogen fixation, phytohormone production and phosphate solubilization properties (Narula et al. 1998, Kumar et al. 2001).

The responsiveness of wheat varieties in terms of improved performance of different traits to microbes greatly differs and these differences are due to the genetic background of the varieties (Behl et al. 2003). Wheat genotypes having improved root length density (RLD), a large number of spikes per m^2 and seed weight support microbe symbiosis in low input environment (Manske et al. 2000). It would be thus imperative to understand the gene effects governing inheritance of various traits in wheat to harness such favourable plant host-microbe interaction.

The present study was initiated to evaluate the impact of AMF and dual inoculation of AMF + Azc on performance and gene effects of important plant characters and grain yield under low input field conditions.

MATERIAL AND METHODS

Genetically diverse three wheat (*Triticum aestivum* L.) varieties suitable for different agro-ecological conditions namely WH 147 (low mineral input), WH 533 (water deficit) and Raj 3077 (high mineral input) were involved in crosses. Six generations (P_1, P_2, F_1, F_2, BC_1, BC_2) of three crosses viz. WH 147 ×

WH 533, WH 533 × Raj 3077 and WH 147 × Raj 3077 were evaluated in randomised block design with three replications under low input field conditions (80 kg N + 40 kg P + 18 kg $ZnSO_4$) keeping three treatments i.e. control, inoculation of arbuscular mycorrhiza fungi (AMF) and dual inoculation of AMF + *Azotobacter chroococcum* (AMF + Azc). Two rows each of F_1s and parents, ten rows of F_2s and four rows of backcrosses were planted keeping row to row and plant to plant spacing within a row as 30 and 10 cm, respectively.

For AMF inoculation, pearl millet roots infected with arbuscular mycorrhiza fungi *Glomus fasciculatum* were chopped to small pieces and mixed with soil in furrows at the time of sowing. *Azotobacter chroococcum* mutant Mac27 (methyl ammonium chloride resistant) was grown on nitrogen free Jensen medium (Jensen 1951) containing 2 per cent sucrose at 30°C for 72 hrs. For Azc inoculation wheat seeds were first treated with traditional jaggery or molasses solution prior to treatment with charcoal based *Azotobacter chroococcum* Mac27 in a beaker and shaken thoroughly to facilitate uniform coating of seeds with the inoculum using colony forming units (CFU) 10^9 cells/ml. CFU was determined by plate count method (Narula et al. 2002). Azc treated seeds were kept under shade for about one hour for drying before sowing so that Azc inoculum could adhere to seeds nicely. For dual inoculation pre-inoculated wheat seeds with Azc were co-inoculated with AMF.

In both the bio-inoculants treated plots, mineral fertilizer dose was the same as that of control. The soil of CCS Haryana Agricultural University, Hisar, India farm is sandy loam, alluvial in nature having pH 8.5, organic carbon 0.35%, total nitrogen 0.034% and available phosphate 4.2 mg/kg.

Observations on five plants of non-segregating generations (parents and F_1s), fifty plants in F_2 and twenty five plants in each of the backcross generations of each of the three crosses in each replication were recorded for days to flowering, days to maturity, plant height (cm), peduncle length (cm), flag leaf area (cm^2), tillers per plant, spike length (cm), grains per spike, 1000-grain weight (g), grain yield (g) and harvest index (%). The mean and variances of individual families were calculated and used for the estimation of gene effects (Jink and Jones 1958). The adequacy of additive-dominance model was determined by joint scaling tests suggested by Cavalli (1952).

RESULTS

Mean performance. In general, the impact of bio-inoculation of AMF and AMF + Azc on mean performance of parents, F_1, F_2, BC_1, BC_2 was seen for all the traits. However, comparative evaluation of the magnitude of impact for various traits in different crosses and their generations revealed that such effects were cross specific. For brevity only those crosses which exhibited significant differences for estimate of mean (m) between control and inoculated treatments for various traits have been presented in Table 1. For days to flowering, days to maturity, peduncle length, tillers per plant and spike length the populations of the crosses WH 147 × WH 533 and WH 147 × Raj 3077 responded to AMF and/or AMF + Azc treatments while for plant height, flag leaf area, grain yield and biological yield such response was observed in the crosses, WH 147 × WH 533 and WH 533 × Raj 3077. Most of the generations of all the three crosses for harvest index and 1000-grain weight and of WH 533 × Raj 3077 for grain yield responded to bioinoculants. The treatments of bio-inoculants caused lateness and reduction in plant height but increased mean performance for tillers/plant, spike length, flag leaf area and grain weight in cross WH 147 × WH 533. However, the reverse was true for these traits in the cross WH 147 × Raj 3077. For the rest of the traits, treatment with bio-inoculants had enhancing effect on mean in populations of all the three crosses.

Gene effects. The non-significance of chi-square values in joint scaling tests suggested by Cavalli (1952), indicated adequacy of additive-dominance model implying that inheritance of peduncle length. Tillers per plant, spike length, grain yield and biological yield in all the crosses under three treatments (control, AMF and AMF + Azc) was mainly governed by additive (d) and dominance (h) gene effects. In control, additive gene effects mainly governed the plant height while for days to maturity, flag leaf area and 1000-grain weight both additive and dominance gene effects were important. The estimates of *d* or *h* were significant only for specific crosses/treatment and have been presented in Table 2. The significance of chi-square values of the joint scaling tests indicated the presence of digenic interactions (additive × additive, additive × dominance, dominance × dominance). These were exhibited for flag leaf area, spike length, 1000 grain weight and grains per spike in the cross WH 147 × Raj 3077 and for harvest index and days to flowering in all the three crosses in the control treatment (Table 3). The treatment of bio-inoculants had their definite impact on genetic mechanisms governing days to flowering, days to maturity, flag leaf area, spike length, grains/spike, 1000-grain weight and harvest index where complex genetic interactions were changed to simple additive-dominance gene effects in the cross WH 147 × Raj 3077. While additive-dominance gene effects were altered to digenic interactions for days to maturity, flag leaf area in WH 147 × WH 533 and

Table 1. Mean performance (m) of six generations of three crosses exhibiting significant differences between control and bioinoculant treatments for plant characters in wheat

Characters	Crosses	Mean performance (m)		
		control	AMF	AMF + Azc
Days to flowering	WH 147 × WH 533	82.44 ± 0.41	85.31 ± 0.34	85.31 ± 0.36
	WH 147 × Raj 3077	86.48 ± 0.28	84.74 ± 0.33	85.95 ± 0.44
Days to maturity	WH 147 × WH 533	111.21 ± 0.60	108.96 ± 0.79	110.52 ± 0.72
	WH 147 × Raj 3077	111.95 ± 0.74	109.34 ± 0.64	110.73 ± 0.76
Peduncle length (cm)	WH 147 × WH 533	11.35 ± 1.20	11.56 ± 1.24	–
	WH 147 × Raj 3077	10.66 ± 1.05	12.10 ± 1.31	–
Number of tillers per plant	WH 147 × WH 533	11.86 ± 1.74	13.14 ± 2.09	13.76 ± 1.98
	WH 147 × Raj 3077	14.20 ± 1.96	12.41 ± 2.31	13.58 ± 2.10
Spike length (cm)	WH 147 × WH 533	9.42 ± 0.28	9.84 ± 0.43	9.85 ± 0.40
	WH 147 × Raj 3077	11.11 ± 0.51	9.97 ± 0.44	10.28 ± 0.43
Plant height (cm)	WH 147 × WH 533	82.41 ± 1.29	79.73 ± 2.22	80.48 ± 1.53
	WH 533 × Raj 3077	–	85.98 ± 1.55	83.89 ± 1.48
Flag leaf area (cm^2)	WH 147 × WH 533	38.89 ± 1.72	40.41 ± 1.37	46.88 ± 1.78
	WH 533 × Raj 3077	32.93 ± 1.86	38.53 ± 1.44	41.68 ± 1.63
Grain yield per plant (g)	WH 147 × WH 533	15.94 ± 1.53	18.83 ± 2.17	17.49 ± 1.80
	WH 533 × Raj 3077	15.74 ± 2.64	17.67 ± 2.64	18.65 ± 2.18
Biological yield per plant (g)	WH 147 × WH 533	34.33 ± 1.88	37.37 ± 2.25	35.58 ± 2.43
	WH 533 × Raj 3077	34.95 ± 2.33	36.88 ± 2.36	38.47 ± 2.34
Harvest index (%)	WH 147 × WH 533	43.52 ± 4.02	49.77 ± 0.93	47.41 ± 0.90
	WH 533 × Raj 3077	44.80 ± 1.11	46.68 ± 1.13	46.68 ± 0.99
	WH 147 × Raj 3077	39.77 ± 1.01	43.27 ± 0.78	45.14 ± 0.96
1000-grain weight (g)	WH 147 × WH 533	27.27 ± 1.27	29.97 ± 1.29	34.66 ± 1.09
	WH 533 × Raj 3077	31.07 ± 0.97	30.97 ± 1.45	33.56 ± 1.07
Number of grains per spike	WH 147 × WH 533	–	–	53.17 ± 2.12
	WH 533 × Raj 3077	49.87 ± 2.35	53.80 ± 2.53	53.26 ± 3.28
	WH 147 × Raj 3077	–	54.95 ± 2.45	54.29 ± 2.66

AMF = arbuscular mycorrhiza fungi, Azc = *Azotobacter chroococcum*, m = estimates of mean performance based on six generations

days to flowering, plant height, flag leaf area in WH 533 × Raj 3077. Such changes were mostly in dual inoculation of AMF + Azc.

DISCUSSION

The improved performance with bio-inoculants for days to flowering, days to maturity, peduncle length, tillers/plant, spike length in the crosses WH 147 × WH 533 and WH 147 × Raj 3077 and for other traits in the cross WH 147 × Raj 3077 under low input field conditions was probably due to the absorption of more nutrients by wheat plants because AMF treatment provided access to more soil volume as extra matrical hyphae of AM fungi enlarge the effective surface outside of the roots (Manske 1990, Manske et al. 1995). Such cross specific beneficial effect on productivity of wheat crop of *Azotobacter chroococcum*, as a soil inoculant, has also been reported in wheat crop (Narula et al. 1998). Manske et al. (2000) and Behl et al. (2002, 2003) have also observed synergistic effects between AMF and Azc.

Table 2. Gene effects (additive and dominance) in three wheat crosses for plant traits under different bioinoculation treatments

Characters	Treatments	WH 147 × WH 533		WH 533 × Raj 3077		WH 147 × Raj 3077	
		d	*h*	*d*	*h*	*d*	*h*
Days to flowering	control	digenic	digenic	digenic	digenic	digenic	digenic
	AMF	1.14 ± 0.34**	2.68 ± 0.65**	–0.38 ± 0.37	–3.65 ± 0.65**	digenic	digenic
	AMF + Azc	0.74 ± 0.36	1.65 ± 0.72**	digenic	digenic	0.06 ± 0.44	–0.76 ± 0.65
Days to maturity	control	1.00 ± 0.59	2.22 ± 0.87	–0.36 ± 0.74	–1.15 ± 1.25	0.22 ± 0.75	–0.49 ± 1.23
	AMF	digenic	digenic	–1.84 ± 0.65**	–4.01 ± 0.94**	–0.70 ± 0.62	–2.49 ± 1.33
	AMF + Azc	digenic	digenic	–0.83 ± 0.73	–0.84 ± 1.33	–0.38 ± 0.73	0.38 ± 1.34
Plant height (cm)	control	1.84 ± 1.21	–3.86 ± 2.22	3.52 ± 1.37**	0.35 ± 2.41	2.47 ± 1.55	–1.25 ± 2.78
	AMF	–1.32 ± 2.14	–1.02 ± 3.82	3.03 ± 1.48*	–2.96 ± 3.09	2.87 ± 1.70	–2.54 ± 3.10
	AMF + Azc	–1.01 ± 1.55	–1.21 ± 2.21	digenic	digenic	digenic	digenic
Flag leaf area (cm^2)	control	–9.67 ± 1.69**	–5.36 ± 3.06	3.14 ± 1.88	5.73 ± 2.90*	digenic	digenic
	AMF	–6.81 ± 1.37**	–0.77 ± 2.09	digenic	digenic	–6.64 ± 1.77**	–1.07 ± 3.39
	AMF + Azc	digenic	digenic	6.82 ± 1.60**	–7.53 ± 3.08*	–5.55 ± 1.80**	0.91 ± 3.69
1000-grain weight (g)	control	–6.24 ± 1.17**	11.15 ± 2.59**	1.65 ± 0.97	3.37 ± 1.81	digenic	digenic
	AMF	–0.52 ± 1.28	0.67 ± 2.35	0.67 ± 1.46	0.96 ± 2.03	0.27 ± 1.26	2.77 ± 1.97
	AMF + Azc	–0.78 ± 1.08	3.34 ± 1.87	0.75 ± 1.04	–2.58 ± 1.88	–0.24 ± 1.22	0.84 ± 2.13
Number of grains per spike	control	0.36 ± 2.37	1.10 ± 4.17	–1.92 ± 2.35	–0.22 ± 3.57	digenic	digenic
	AMF	0.35 ± 2.60	–0.31 ± 3.94	–1.39 ± 2.56	–4.28 ± 3.45	digenic	digenic
	AMF + Azc	–0.55 ± 2.07	1.08 ± 4.14	1.18 ± 3.22	–6.14 ± 5.84	0.66 ± 2.62	–2.25 ± 5.53
Spike length (cm)	control	0.11 ± 0.28	0.62 ± 0.60	0.30 ± 0.40	0.10 ± 0.80	digenic	digenic
	AMF	0.40 ± 0.42	0.35 ± 0.84	0.17 ± 0.45	–0.17 ± 0.96	0.50 ± 0.44	0.33 ± 0.88
	AMF + Azc	0.33 ± 0.37	0.21 ± 0.81	0.26 ± 0.50	–0.22 ± 0.85	0.41 ± 0.41	–0.36 ± 0.85
Harvest index (%)	control	digenic	digenic	digenic	digenic	digenic	digenic
	AMF	1.93 ± 0.91	–9.88 ± 2.01	–5.67 ± 1.10**	3.43 ± 1.94	–2.50 ± 0.79	–1.73 ± 1.52
	AMF + Azc	–0.16 ± 0.89	3.40 ± 1.69	–4.62 ± 0.98**	1.43 ± 1.75	–2.48 ± 0.94**	–4.28 ± 1.73*

*significant at 5% level, **significant at 1% level

AMF = arbuscular mycorrhiza fungi, Azc = *Azotobacter chroococcum*

digenic = significant chi-square values of joint scaling tests, *d* = additive gene effect, *h* = dominance gene effect

The genetic control of peduncle length, flag leaf area, spike length, grain weight, grain yield and biological yield was mainly due to additive effects and bio-inoculants had enhanced the magnitude or significance of these effects. The importance of additive effects was reported by earlier workers for component traits like plant height (Katiyar and Ahmad 1996), spike length (Walia et al. 1991), grain weight (Walia et al. 1991, Singh and Singh 1992), flag leaf area (Prodanovic 1993) and grains per spike (Rosal et al. 1991) while dominant effects were reported to be important for tillers per plant as was the case in present study. The digenic interactions became predominant after the treatment with bio-inoculants. Sharma (1998) reported similar results. The importance of epistatic effects was reported for grain yield (Nanda et al. 1990), plant height, grain weight (Amawate and Behl 1995) and grains per spike (Verma and Yunus 1986).

Considerable magnitude of additive and additive × additive gene effects for plant height, days to flowering, grains per spike and grain weight suggested that simple pedigree selection would be effective to develop wheat genotypes which are responsive to dual inoculation of AMF and Azc. Moreover, indirect selection for the above ground

Table 3. Estimates of digenic interactionsin three wheat crosses for plant traits under different bioinoculation treatments

	Cross	*d*	*h*	*i*	*j*	*l*	Epi-stasis
Days to flowering							
	WH 147 × WH 533	–2.33 ± 0.70**	–0.56 ± 2.62	1.48 ± 1.60	2.27 ± 1.46	1.71 ± 2.10	–
Control	WH 533 × Raj 3077	1.66 ± 0.71*	22.80 ± 3.06**	6.68 ± 1.93**	–2.01 ± 1.62	–14.91 ± 2.41**	D
	WH 147 × Raj 3077	–0.17 ± 0.63	34.21 ± 3.04**	11.68 ± 2.04**	–2.66 ± 1.38	–19.70 ± 2.29**	D
AMF	WH 147 × Raj 3077	0.00 ± 0.53	17.00 ± 2.88**	5.66 ± 1.90**	0.34 ± 1.35	–10.00 ± 2.20**	D
AMF + Azc	WH 533 × Raj 3077	1.33 ± 0.61*	26.33 ± 3.33**	10.00 ± 2.21**	–0.67 ± 1.55	–15.33 ± 2.53**	D
Days to maturity							
AMF	WH 147 × WH 533	–1.00 ± 0.88	–7.68 ± 3.64**	–3.34 ± 2.39	–5.34 ± 1.76**	2.00 ± 2.84	–
AMF + Azc	WH 147 × WH 533	–1.00 ± 0.88	32.31 ± 3.41**	12.60 ± 2.33**	0.21 ± 1.43	–21.01 ± 2.60**	D
Plant height							
AMF	WH 533 × Raj 3057	–0.83 ± 1.17	–21.95 ± 5.46**	–8.86 ± 3.70*	–19.79 ± 2.33**	15.73 ± 4.14**	D
AMF + Azc	WH 147 × Raj 3057	2.26 ± 0.98*	–4.15 ± 6.30	–9.00 ± 4.35	–7.09 ± 2.31	2.49 ± 4.60	D
Flag leaf area							
Control	WH 147 × Raj 3077	2.47 ± 1.33	174.95 ± 6.11**	75.24 ± 4.08**	20.78 ± 2.82**	–104.82 ± 4.65**	D
AMF	WH 533 × Raj 3077	2.75 ± 1.34*	–27.09 ± 6.54**	0.28 ± 4.42	–13.94 ± 2.82**	33.42 ± 4.88**	D
AMF + Azc	WH 147 × WH 533	8.67 ± 1.46**	–142.23 ± 6.62**	–44.04 ± 4.38**	–14.15 ± 3.14**	80.93 ± 5.05**	D
Spike length							
AMF + Azc	WH 147 × Raj 3077	0.02 ± 0.63	17.96 ± 3.97**	4.72 ± 2.73	–2.41 ± 1.49	–11.03 ± 2.93**	D
Number of grains per spike							
Control	WH 147 × Raj 3077	–2.44 ± 1.76	175.53 ± 7.49**	58.70 ± 5.05**	–5.77 ± 3.37	–120.93 ± 5.63**	D
AMF	WH 147 × Raj 3077	1.58 ± 1.66	92.31 ± 8.23**	35.88 ± 5.58**	20.83 ± 3.53**	–55.05 ± 6.14**	D
1000-grain weight							
Control	WH 147 × Raj 3077	2.80 ± 1.11*	41.29 ± 5.16**	12.10 ± 3.52**	–3.42 ± 2.17	–27.18 ± 3.84**	D
Harvest index							
	WH 147 × WH 533	–1.38 ± 1.07	–56.06 ± 4.39**	–14.14 ± 2.87**	5.78 ± 2.18**	41.16 ± 3.38**	D
Control	WH533 × Raj3077	1.33 ± 1.11	10.49 ± 4.53*	11.58 ± 2.92**	17.36 ± 2.31**	–5.06 ± 3.53	–
	WH147 × Raj3077	2.06 ± 1.04	–35.98 ± 4.32**	–6.72 ± 2.82**	–2.04 ± 2.14	34.20 ± 3.40**	D
AMF	WH147 × WH533	–2.62 ± 0.99**	–119.82 ± 4.73**	–39.52 ± 3.10**	5.65 ± 2.28*	74.63 ± 3.67**	D
	WH147 × Raj3077	2.66 ± 0.91	39.75 ± 4.29**	9.98 ± 2.71**	–3.63 ± 2.25	–33.41 ± 3.40**	D
AMF + Azc	WH147 × WH533	–0.57 ± 0.98	–116.59 ± 4.43**	–34.48 ± 2.86**	3.22 ± 2.24	81.98 ± 3.46**	D

*significant at 5% level, **significant at 1% level

AMF = arbuscular mycorrhiza fungi, Azc = *Azotobacter chroococcum*

d = additive gene effects, *h* = dominance gene effects, *i* = additive × additive gene effects, *j* = dominance × dominance gene effects, *l* = additive × dominance gene effects, D = duplicate epistasis

traits like the number of tillers shall provide genotypes with improved root system (Manske et al. 2000). The productiveness of rhizosphere for AMF may be attributed to favourable influence exerted by root exudates (Leinhos and Vacek 1994), which contain amino acids, carbohydrates, organic acids and growth promoting substances and also phytohormones produced by *Azotobacter*. It is a well known fact that wheat roots secrete carbonaceous exudates, which could help in proliferation of AMF and *Azotobacter* (Manske et al. 2000). *Azotobacter* excretes phytohormones, which improves growth of plant roots, and AMF may solubilize P from surrounding areas and makes it available to the roots. Dual inoculation of efficient strains of *Azotobacter chroococcum* and *Glomus fasiculatum* in responsive wheat genotypes adapted to low input stress conditions could be profitably used to maximize wheat production. However, intense AMF infected roots even at moderate nutrient deficiency are important during early plant growth when roots are too small to provide a high demand for minerals for shoot growth. In this context, selection of potent recombinants in crosses involving wheat variety WH 147 suitable for medium fertility and water deficit conditions holds great promise to develop bio-inoculants responsive high yielding genotypes for stress prone low input conditions. Thus pedigree selection in crosses WH 147 × WH 533 and WH 147 × Raj 3077 can be effective for breeding pure lines in wheat for sustainable agriculture (low input genotypes responsive to biofertilizers like AMF and *Azotobacter*). On the other hand, cross WH 533 × Raj 3077 would yield potent recombinants for high input conditions. In any eventuality, such genotypes will be efficient to make better use of applied nutrients and suitable for sustainable wheat production under diverse agro-ecological conditions.

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ABSTRACT

Vliv inokulace arbuskulo-mykorhizními houbami a *Azotobacter chroococcum* na projevy a účinek genů u pšenice

Výzkum byl zaměřen na poznání vlivu bioinokulantů na expresi různých genotypů tří odrůd pšenice (WH 147 – vhodná pro střední úroveň výživy, WH 533 – tolerantní k suchu, Raj 3077 – tolerantní k suchu) a šesti generací P_1, P_2, F_1, F_2, BC_1 a BC_2 tří kříženců: WH 147 × WH 533, WH 533 × Raj 3077 a WH 147 × Raj 3077. Pokus byl založen metodou náhodných bloků se třemi opakováními a třemi ošetřeními: kontrola (C, bez inokulace), inokulace arbuskulo-mykorhizní houbou (AMF, *Glomus fasciculatum*) a AMF + *Azotobacter chroococcum* (Azc). Minerální hnojení (80 kg N/ha + 40 kg P/ha + 18 kg $ZnSO_4$/ha) bylo použito ve všech třech ošetřeních. Aplikace bioinokulantů (AMF a AMF + Azc) měla pozitivní vliv na výšku rostlin, délku klasového vřetena, výnos zrna, biologický výnos a sklizňový index v různých populacích všech křížení. Nicméně v některých generacích nebyl vliv bioinokulantů signifikantní. „The joint scaling test" prokázal, že aditivně-dominantní vliv genů se projevil hlavně u délky klasového vřetena, počtu stébel jednotlivých rostlin, výšky rostlin, počtu zrn v klasu, výnosu zrna a všech znaků s výjimkou počtu dnů do začátku kvetení a sklizňového indexu u kříženců WH 147 × WH 533 a WH 533 × Raj 3077. Aplikace bioinokulantů ovlivnila projev genů v počtu dnů do začátku kvetení, počtu dnů do zralosti, ploše praporcovitého listu, délce klasu, počtu zrn v klasu, hmotnosti 1000 zrn a sklizňovém indexu, kdy komplexní genetické interakce byly změněny na jednoduchý aditivně-dominantní vliv genů u křížence WH 147 × Raj 3077. Také aditivně-dominantní vliv genů byl změněn a interakce dvou genů se projevily v počtu dnů do zralosti a ploše praporcovitého listu u WH 147 × WH 533 a v počtu dnů do začátku kvetení, výšce rostlin a ploše praporcovitého listu u WH 533 × Raj 3077. Plocha praporcovitého listu a výška rostlin byla řízena vlivem aditivních genů, zatímco pro počet dnů do zralosti a hmotnost 1000 semen byl významný jak aditivní, tak dominantní vliv genů. Dvojitá epistaze byla významná ve všech třech kříženích pro počet dnů do začátku kvetení a sklizňový index, u křížence WH 147 × Raj 3077 pro hmotnost zrn, počet zrn v klasu a plochu praporcovitého listu.

Klíčová slova: pšenice; *Azotobacter chroococcum*; arbuskulo-mykorhizní houby; vliv genotypu

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