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Genetic variability and advance under four selection procedures in wheat pedigree breeding programme *

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Summary. Four methods of generation advance (SPS, SSD, BP and MMS) were compared in F_3 and F_4 generations. In the F_3 generation, the SPS and SSD methods of generation advance proved superior to the BP and MMS methods for grain yield per plant and for at least one of the yield component traits. The F_3 SSD population did not differ significantly from the F_3 SPS for any of the traits. However, the F_3 SSD population retained more range and cv for different traits than with other methods of generation advance. F_4 progenies derived from F_3 SSD population were significantly superior for grain yield than lines derived from the other three F_3 populations. The MMS method of generation advance proved useful for increasing the 1,000-grain weight for which initial selection was made.

Key words: Wheat – Single seed descent (SSD) – Single plant selection (SPS) – Bulk population (BP) – Mechanical mass selection (MMS)

Introduction

India has realized a quantum jump in wheat productivity through the removal of bottlenecks in production, by manipulating the dwarfing and disease-resistance genes which made wheat plant responsive to agronomic practices and resistant to lodging. Further breakthroughs in improving the wheat yield have become relatively difficult during the last 15 years. One of the reasons may be the inadequacy of directional selection in pedigree breeding methods to exploit the range of useful genetic variability for grain yield and its component traits, as observed in the pre-green revolution era by Allard and Hansche (1964). Single-seed descent (SSD) and some other selection schemes have been suggested to obtain higher-realized gain in segregating generations (Mc Ginnies and Shebeski 1968; Dahiya and Singh 1986). Keeping this in mind, the present investigation was carried out to compare the efficiency of four methods of generation advance.

Materials and methods

Two intervarietal crosses of wheat, HD 2009 × Sonalika and Kalyansona × Sonalika, involving elite parents were made during the main season 1982–1983. The F_1s were grown in the off-season (1982–1983) at Lahual Spiti, to get the F_2 seeds of these crosses. A large F_2 population comprising about 10,000 plants was raised for each cross at Haryana Agricultural University, Hisar, during 1983–1984. Four selection schemes, viz. (1) Single Plant Selection (SPS), (2) Single-Seed Descent (SSD), (3) Bulk Population (BP) and (4) Mechanical Mass Selection (MMS), were applied to advance the F_2 generation of both the crosses.

In the SPS method, individual plants selected on the basis of plant vigour, seed characteristics and disease resistance were harvested separately. Half of the seed of selected plants was used to raise F_3 progenies during the off-season of 1983–1984. Twenty-five agronomically superior single plants were harvested in F_3 to constitute F_4 SPS progenies. The remanent seed of selected F_2 plants was kept separate to form the F_3 SPS population in the next season.

In the SSD method, two seeds were separately harvested from each F_2 plant. A single seed of each F_2 plant was used to grow the F_3 SSD population during the off-season 1983–1984. At maturity, 25 random plants in each F_3 SSD population were harvested to constitute the F_4 SSD progenies. Another lot of single seed from each F_2 plant was kept separate to form F_3 SSD populations of both the crosses in the next season.

In the bulk population method, F_2 plants of each cross were harvested and seed was bulked. The bulked F_2 seeds had the

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representative seeds from each F_2 plant selected under the SPS method. Two random samples of seed were drawn from the F_2 bulk of each cross. One sample of bulked seed of each cross was space-planted in the off-season 1983–1984. Twenty-five plants from each F_3 BP population were randomly selected at maturity and harvested separately to constitute F_4 BP progenies in the next season. The remanent seeds of F_2 bulks of two crosses were kept separately to constitute the F_3 BP population in the following season.

In the case of mechanical mass selection, the F_2 bulked seed was sieved to separate bold seed in both the crosses. A portion of sieved seed of both the crosses was sown in the off-season. At maturity, 25 randomly selected F_3 plants were harvested separately, which constituted F_4 MMS progenies in the next season, the remaining portion of sieved seed constituted the F_3 MMS population in the next season. Finally, four populations, namely F_3 SPS, F_3 SSD, F_3 BP and F_3 MMS, and 25 progenies of each of the four methods of generation advance were growth during the 1984–1985 crop season, to compare the relative efficiencies of selection methods. Twenty-five plots of each of the F_3 population, and 25 corresponding F_4 progenies evolved in each method of generation advance, along with the parents, were grown in randomized complete block design with three replications. Each plot consisted of 3.5 m long rows, spaced at 25 cm with a plant-to-plant distance of 15 cm. The material generated from each cross was evaluated separately. The observations were recorded on five randomly selected plants for five traits, viz. tillers per plant, grains per ear, 1,000-grain weight (grams), biological yield per plant (grams) and grain yield per plant (grams). The comparisons were made on the basis of mean, range, coefficient of variation, heritability (h^2) and genetic advance (GA). Accordingly, data were subjected to statistical analysis following the standard statistical procedures.

Results and discussion

The analysis of variance showed that F_3 and F_4 populations advanced through four methods of generation advance differed significantly from each other in both of the crosses. Significant values of mean squares due to SPS versus SSD, SPS versus BP and SPS versus MMS in the F_4 generation revealed that F_4 progenies derived from the F_3 SSD population differed significantly from the SPS method for grain yield per plant in both the crosses. Differences between F_4 SPS and F_4 MMS and F_4 SPS and F_4 BP progenies were significant for all the traits in both the crosses, except F_4 SPS versus F_4 BP differences for grains per ear and grain yield per plant in Cross I. These four methods of generation advance, therefore, had differential impact on changing the mean of the populations, as also observed by Pawar et al. (1986).

The mean and range of various F_3 and F_4 populations generated through different methods of generation advance are given in Table 1 for Crosses I and II. The low values of grain yield in proportion to biological yield may be attributed to the abrupt rise in temperature during the grain filling period, particularly at the time of maturity. This may also be the reason for realizing low values of 1,000-grain weight. Values of least significant difference were calculated for all the traits in both the generations to compare the means. A significantly higher mean of the F_3 SPS population over the BP and MMS populations for tillers per plant and grain yield per plant in Cross I and tillers per plant, grains per ear and grain yield per plant in Cross II, showed the superiority of the SPS method over the BP and MMS methods. Similar observations were made by Knott (1972) and Alessandroni and Scalfati (1973). The variability in F_3 progenies derived through the SPS method was comparatively lower than in the SSD and BP methods, but the mean performance of the F_3 SPS population was on a par with the F_3 SSD population and superior to other methods for all the traits. The directional selection appears to reduce the range and variability for different traits in the F_3 SPS population without affecting the mean.

Thus, the SSD and SPS methods of generation advance were superior to the other methods of generation advance. The F_3 SSD method showed a significantly higher mean over the F_3 BP and F_3 MMS for tillers per plant and grain yield per plant in both of the crosses. It was also significantly superior to the F_3 MMS for grain per ear in both of the crosses. The range of the F_3 SSD population was higher than the F_3 BP nd F_3 MMS for most of the traits, since it retains more variability, as all the individual plants of F_2 are represented. Theoretically, also the SSD must retain more variability (Roy 1976). This is experimentally demonstrated in the present study as well as in those of Kumar (1973) and Tee and Qualset (1975) in wheat.

The F_3 MMS population has shown significantly higher mean for 1,000-grain weight and biological yield per plant over other methods of generation advance in Cross I and only over the F_3 BP in Cross II. The mean of the F_3 MMS for 1,000-grain weight was higher over other populations in Cross II, due to initial selection for seed size. The positive correlations of seed size with plant height (Rana et al. 1983; Rana 1984) appear to influence the bilogical yield under this method. Thus the MMS method of generation advance may be promising for the improvement of those traits for which initial selection was made. Similar effects were also reported by Mehla et al. (1981) and Rana (1984).

The low performance of the F_3 BP and F_3 MMS methods for grain yield per plant in both the crosses may be seen in the context of the bulk population breeding approach. Studies on bulk population breeding have shown that natural selection exerts a dynamic influence on the composition of population at each generation, resulting in change of gene frequencies as the hybrid moves towards homozygosity. Due to natural selection and competition effects, the performance of bulk population is reduced (Jennings and Herrera 1968; Khalifa and Qualset 1975; Tee and Qualset 1975). If the physiological factors that affect the competitive ability are not recognized, the SSD method of generation advance has great

Table 1. Variability in F_3 and F_4 populations developed through different selection methods in two crosses of wheat

Statistics	Selection method	Tillers per plant (No.)		Grains per ear (No.)		1,000-grain weight (grams)		Biological yield per plant (grams)		Grain yield per plant (grams)	
		F_3	F_4	F_3	F_4	F_3	F_4	F_3	F_4	F_3	F_4
Cross I: HD 2009 × Sonalika											
Mean	SPS	15.9	19.3	67.1	54.3	40.1	40.7	86.5	99.4	28.4	30.4
	SSD	11.8	18.6	66.1	58.4	41.1	41.1	84.6	98.7	26.7	33.5
	BP	7.0	10.9	69.1	54.0	37.1	38.5	79.1	87.7	22.1	28.9
	MMS	6.8	10.6	52.7	51.9	44.8	49.3	100.8	103.6	19.1	27.6
Range	SPS	5–25	7–36	38–84	34–73	37.1–50.5	36.0–55.3	45.6–205.3	75.6–150.8	12.3–63.1	15.0– 75.0
	SSD	3–30	5–42	22–89	33–75	23.1–52.8	24.0–52.0	35.6–235.6	37.4–150.6	11.4–70.9	16.3– 90.4
	BP	4–29	4–25	28–74	36–75	35.2–43.4	34.7–45.2	41.2–215.9	75.6–150.8	11.7–49.5	15.0– 75.1
	MMS	5–12	10–21	26–64	32–91	37.3–59.0	36.6–60.0	40.6–190.0	29.0–175.3	12.8–48.7	6.2–100.2
CV %	SPS	37.1		10.4		23.2		11.7		29.5	
	SSD	81.1		12.9		27.6		17.2		37.2	
	BP	118.4		12.2		26.0		16.7		43.1	
	MMS	125.4		15.3		20.8		12.7		44.0	
Cross II: Kalyan-sona × Sonalika											
Mean	SPS	13.3	15.7	73.2	64.1	45.0	47.1	115.5	121.5	56.3	49.5
	SSD	12.0	15.1	69.1	62.9	44.6	46.7	118.8	119.9	51.9	53.9
	BP	6.3	12.4	64.0	52.4	39.7	43.4	78.2	81.8	32.2	32.9
	MMS	9.4	9.8	57.8	46.7	47.3	53.1	108.2	93.6	38.8	27.3
Range	SPS	6–20	5–23	32–89	33–96	28.8–57.8	29.3–59.1	54.1–136.0	50.1–151.6	10.0–95.2	10.0–95.2
	SSD	4–32	4–32	19.94	30–87	25.6–60.9	30.1–57.2	51.2–132.6	56.3–139.9	8.2–75.1	8.2–75.1
	BP	3–18	3–52	30–92	36–84	24.0–42.8	36.2–55.3	45.0– 89.2	51.2– 96.3	5.1–80.7	5.1–80.7
	MMS	5–21	4–48	33–68	30–96	32.3–51.4	36.1–59.3	29.2–101.4	16.3–119.8	5.9–72.1	5.9–72.1
CV %	SPS	48.9		13.6		16.5		10.3		15.6	
	SSD	67.3		15.2		19.1		13.7		20.1	
	BP	123.7		16.2		22.3		16.4		30.7	
	MMS	63.6		14.3		16.1		9.3		19.9	

Table 2. Heritability, genetic advance as a percentage of mean and average of five superior progenies developed through different selection methods in two crosses of wheat

Selection method	Heritability (h^2) (%)		Genetic advance (GA)		Mean of 5 top progenies		Number of progenies superior to better parent	
	CI	CII	CI	CII	CI	CII	CI	CII
Tillers per plant								
SPS	42.1	38.4	21.8	12.4	20.3	19.2	6	10
SSD	41.4	33.8	16.8	12.6	22.0	17.3	7	8
BP	16.2	37.8	12.5	12.4	13.8	15.8	3	8
MMS	15.7	34.3	9.7	11.5	14.6	14.5	3	6
Grains per ear								
SPS	60.2	58.8	5.3	16.7	67.3	70.0	15	7
SSD	52.1	45.6	5.1	7.9	63.1	72.3	15	9
BP	24.6	52.1	3.5	8.6	58.4	63.8	18	5
MMS	32.9	25.3	2.6	2.4	52.9	59.2	6	4
1,000-grain weight								
SPS	79.0	74.9	4.4	11.7	43.3	48.8	11	14
SSD	71.3	84.1	3.1	13.5	43.7	48.0	12	14
BP	78.3	63.9	3.7	8.6	39.3	45.0	9	14
MMS	54.8	67.4	7.4	15.1	51.9	54.3	7	19
Biological yield per plant								
SPS	46.6	49.8	13.9	7.5	100.1	125.3	6	10
SSD	52.9	29.7	7.0	6.0	98.4	123.2	7	12
BP	31.6	50.1	9.3	7.4	110.5	101.8	12	9
MMS	35,1	40.1	5.1	7.1	112.8	100.3	13	9
Grain yield per plant								
SPS	40.0	56.8	25.9	18.1	38.6	53.1	8	10
SSD	52.1	45.9	24.0	20.7	39.8	55.3	9	10
BP	45.9	42.8	21.1	12.8	29.3	32.5	7	5
MMS	39.8	40.5	11.5	12.7	27.3	34.8	9	6

CI = HD 2009 × Sonalika
CII = Kalyan-sona × Sonalika

utility over the BP approach for retaining high mean and variability (Tee 1971; Tee and Qualset 1975).

Comparison of mean values of F_4 progenies revealed that lines derived through the SSD method were significantly superior for grain yield to lines derived from the F_3 SPS, F_3 BP and F_3 MMS populations in both the crosses. Lines developed from the F_3 MMS population were significantly superior than the other three methods of generation advance for 1,000-grain weight in both of the crosses. The overall assessment (Table 1) indicated that the SSD method may be a more useful method of generation advance, as it retains relatively high mean and variability for different traits in the population, though its superiority over SPS for grain yield in F_3 could not be established. Empig (1975), Snape and Riggs (1975), Riggs and Snape (1977) and Kumar et al. (1979) also showed that SSD was either equal or superior to other methods of generation advance and, therefore, a large amount of work in single plant selection in F_2 and beyond is not justified.

The heritability and genetic advance for different traits in F_4 progenies are presented in Table 2 for both the crosses. Relatively higher mean and variability coupled with moderate predicted genetic advance was observed for F_4 line derived through the SSD population method for most of the traits in both the crosses, indicating better scope for further improvement in grain yield and its component traits. Baker (1971) and Hill (1974) showed that genetic advance would be more variable if population size is small and selection is intense or h^2 is low. Simulation studies (Casali and Tigchelaar 1975) indicated that the SSD method of generation advance was effective even at very low heritability (h^2). They also postulated that SSD offers the greatest benefits in situations where simultaneous selection is required for several traits under different heritabilities.

The comparison of methods of generation advance on the basis of progenies surpassing the best parent and mean of the five top yielding lines indicated a marginal (3%–4%) superiority of the SSD method over the SPS method for grain yield improvement. In fact, the wheat breeder can realize desirable results quickly if the population has high mean and high variance. Thus, SSD progenies offer better opportunities for the selection of improved lines over other methods, as also suggested by Kumar et al. (1979). The MMS method proved to be useful in improving the 1,000-grain weight. Similar results were obtained by Derera and Bhatt (1972), Hurd et al. (1972) and Rana (1984).

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