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A new selection criterion for yield in wheat

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Summary. The mortality of young tillers to an extent of 36.5% under optimum cultural conditions was recorded in a field experiment. Attention is drawn to the necessity of minimising this loss and to diverting it towards productive tillers by applying selection pressure. Future yield advances may be achieved by selecting genotypes which tiller moderately in the vegetative phase, most of which survive to produce grains. The character association of each variety under consideration was studied for the suitability towards this objective. A modified selection procedure is suggested which may be advantageously applied to achieve this objective. The proposed new methodology may also be effectively applied to such other cereal crops as barley, triticale and oats.

Key words: *Triticum aestivum* – Wheat – Biomass – Harvest index – Selection criterion – Tiller mortality – Modified selection procedure

Introduction

The number of productive tillers per unit area plays a key role in the formation of grain yield in wheat (Bingham 1972; Saini and Nanda 1974; Evans et al. 1975; Jain and Kulshrestha 1976; Saini et al. 1980).

Semidwarf varieties of wheat developed after 'Norin 10' dwarfing genes were exploited in order to produce a larger number of effective tillers than could the taller varieties of yesteryear. This makes them more productive (Saini et al. 1980; Sinha et al. 1981; Kulshrestha and Jain 1978, 1982; Kulshrestha 1985). The number of productive tillers present at the advanced stage of the crop is considerably less than those actually formed; the difference being the result of an early mortality of young tillers (Ishag and Taha 1974; Saini and Nanda 1974) due to several reasons. Pavilov (1971) considered the death of young tillers as lost capital.

With the variation available to breeders both for tiller formation and survival, it may seem possible to divert this loss in the form of dying tillers towards productive ones by applying selection pressure so that the plant exploits all the tillers. This in turn is likely to increase yield under optimal cultural conditions.

This communication draws the breeders' attention to the necessity of curbing this loss by selection. The aim of the present study is to elucidate the association of grain yield with tiller production and mortality, and other related characters. To achieve this objective the breeding methodology in vogue cannot be used without necessary modifications.

Materials and methods

Five improved Indian spring wheat varieties (UP 3005, RAJ 2525, RAJ 2773, PBW 125 and HD 2329) were tested in a field experiment laid out in randomised block design with four replications for tiller production and their survival. Observations at 50, 80 and 120 days after sowing were recorded on three plots of 1 m^2 each which were marked permanently at the very early stage of growth. The test was conducted using a treatment of 100, 80 and 60 kg of N, P and K respectively per hectare. Normal cultural practices were adopted. Post harvest records on yield, biomass, harvest index, 1,000 kernel weight, grain number and grain weight per spike were also taken on each of the marked square metre area. The last two characters were recorded on the specified number of random ears which were later averaged. Tiller mortality on each designated m^2 was calculated as follows:

Tiller mortality (%) =

$$\frac{\text{Max. tillers formed} - \text{Tillers at harvest}}{\text{Max. no. of tillers}} \times 100$$

Table 1. Mean observations on various characters

Variety	Grain yield/m² (g)	Biomass/ m² (g)	Harvest index (%)	No. of tillers/m² at peak	No. of effective tillers/m²	Tiller mortaliy (%)	1,000 kernel wt (g)	Grain no./spike	Grain wt/spike (g)
UP 3005	585.0	1,605.0	36.4	619.5	444.7	28.1	41.3	55.2	1.31
RAJ 2525	605.0	1,650.0	36.8	750.2	477.2	36.5	40.9	52.5	1.26
RAJ 2773	511.2	1,542.5	33.1	718.5	463.5	35.4	35.1	52.6	1.09
PBW 125	571.2	1,640.0	34.8	503.5	349.2	30.3	34.0	63.9	1.62
HD 2329	583.7	1,535.0	38.0	582.2	448.0	23.0	39.2	56.9	1.29
CD at 5%	47.2	56.9	3.0	42.2	21.9	4.6	1.3	5.9	0.12

Table 2. Variance ratio for various characters in wheat varieties

Character	Variance ratio
Grain yield	5.40*
Biomass	8.42**
Harvest index	3.74*
No. of tillers at peak	54.03**
No. of effective tillers	50.31**
Tiller mortality	13.38**
1,000 kernel wt	55.97**
No. of grains per spike	4.97*
Grain wt per spike	24.08**

* Significant at $P=0.05$; ** $P=0.01$

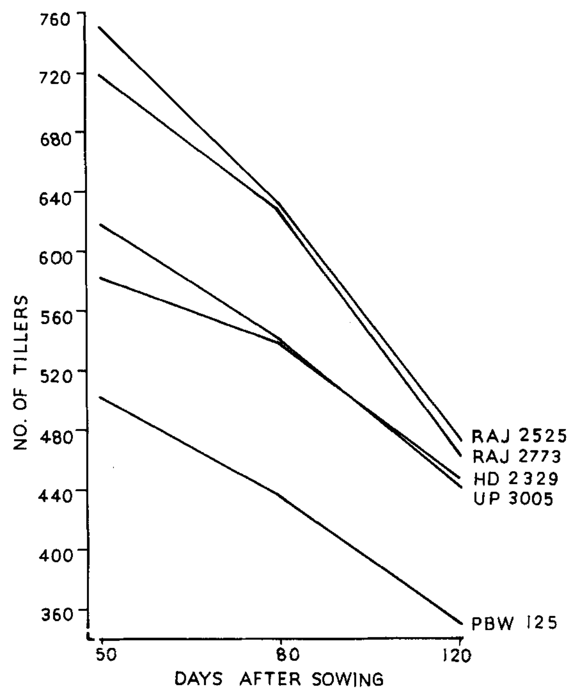

Fig. 1. Number of tillers per m² in five varieties of wheat at 50, 80, and 120 days after sowing

Results

Mean tiller production, tiller mortality, grain yield and other related observations are presented in Table 1. This table shows that varieties exhibit differences in mortality which range from 23.1% in HD 2329 to as much as 36.5% in RAJ 2525. Peak tiller number at 50 days also greatly varies. It is highest in RAJ 2525 and lowest in PBW 125, giving a difference of 33% between the two. A similar trend with respect to these varieties is seen for number of effective tillers (at 120 days) which exhibits a difference of 27%. Other varieties range between these limits. The number of tillers recorded at three stages of plant growth are shown in Fig. 1. The figure clearly shows that a large number of tillers die during the growing period and that the number of dying tillers increases progressively as the plant matures. The variation, which is significant for all characters, is presented in Table 2.

Yield correlations with other characters under study show (Table 3) that the varieties behave differently for their components contributing towards yield. Thus, yield in UP 3005 is seen to be strongly positively correlated with biomass, harvest index and kernel weight but negatively correlated with tiller mortality. In RAJ 2525, yield is positively correlated with biomass, harvest index, number of effective tillers and kernel weight. Though both latter characters are significantly correlated with yield, the degree of association is stronger for tiller number than kernel weight. Yield also shows a strongly negative relationship with tiller mortality while a positive correlation of yield with number of effective tillers and grain weight per spike is observed in RAJ 2773. PBW 125 exhibits a positive correlation of grain yield with biomass, number of effective tillers, grain number per spike and also with grain weight per spike. HD 2329 shows a positive correlation of yield with biomass, harvest index, number of effective tillers and grain weight per spike. However, the degree of correlation is higher in the case of effective tillers than grain weight per spike.

Table 3. Relationship of grain yield with other characters

Variety	Correlation of grain yield with							
	Biomass	Harvest index	No. of tillers/m² at peak	No. of effective tillers/m²	Tiller mortality	1,000 kernel wt	Grain no./ spike	Grain wt/ spike
UP 3005	0.88**	0.89**	0.47	0.50	−0.91**	0.86**	0.46	0.39
RAJ 2525	0.79**	0.63*	0.03	0.78**	−0.67*	0.61*	0.15	−0.18
RAJ 2773	0.47	0.39	0.34	0.59*	−0.46	0.27	0.05	0.86**
PBW 125	0.67*	0.42	−0.31	0.68*	−0.49	−0.06	0.79**	0.59*
HD 2329	0.61*	0.76**	0.35	0.81**	−0.38	0.33	0.28	0.63*

* Significant at $P=0.05$; ** $P=0.01$

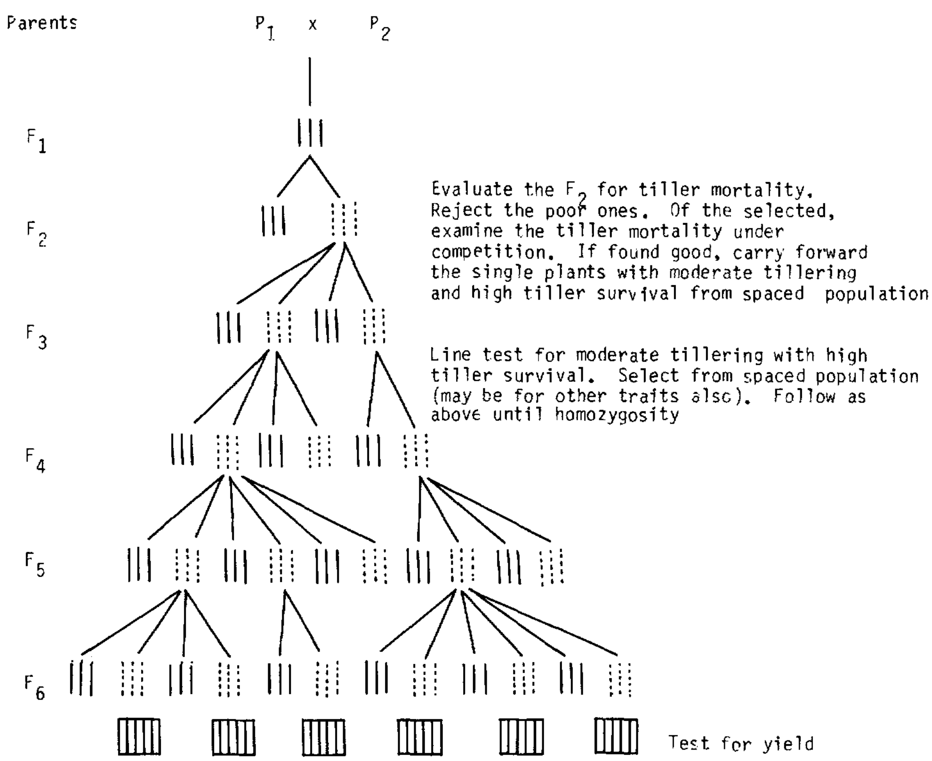

Fig. 2. Schematic representation of the modified procedure of pedigree selection for low tiller mortality in wheat

Discussion

The results clearly indicate that a large number of tillers die during the growing period, an occurrence also reported by Ishag and Taha (1974) and Saini et al. (1980). The mortality increases progressively as the plant matures. Peak tiller production and tiller survival are highly influenced by such environmental conditions as intraplant competition (Simmons et al. 1982), availability of water or natural precipitation (Begg and Turner 1976), radiation (Aspinall and Palag 1964; Friend 1965) and temperature (Rawson 1971; Aspinall and Palag 1964), etc. The varieties differed in their production and survival of tillers. Genetic variation for tiller production and survival has been abundantly reported (Ishag and Taha 1974; Saini et al. 1980; Chaturvedi et al. 1981).

Mortality of tillers, which in this study reaches a high of 36.5%, is clearly a wasteful drain of plant energy which would have otherwise gone into productivity. Evans and Wardlaw (1976) noted that as many as two-thirds of the tillers in cereals may be lost to mortality and that this waste ensures considerable scope for compensation early in life cycle. Many workers (Palfi and Dezsi 1960; Thorne 1962; Lupton and Pinthus 1969; Rawson and Donald 1969) have suggested that dying tillers may contribute their carbon and possibly nitrogen to surviving tillers, whereas others (Williams 1964; Forde 1965; Pavilov 1971; Patrick 1972) considered that dying tillers do not contribute anything to the productive ones. Saini et al. (1980) noted that 10 to 15% of the total dry matter was lost through dead tillers in wheat. If this drain could be curbed or minimised, a large part of it could be usefully utilised in grain production. This aspect of wheat plant improvement has been neglected so far. It is, therefore, necessary that emphasis on genetic manipulation of this character is applied.

With the availability of enough genetic variation for both tiller formation and survival, as also shown in the present study, selection for both these characters must ensure the optimum number of effective tillers. Benbelkacem et al. (1984) noted that because of high tiller mortality, breeding for increased tiller number was only 36% effective in terms of adding additional heads. Producing fewer tillers, all or most of which survive and produce grains, seems to be a more economical proposition for the plant and is characteristic of better yielding types (Bingham 1972). This plant has a definite advantage over the one which tillers profusely in the vegetative phase but ends up with very few effective tillers as a result of high tiller mortality subsequently enduring a substantial loss of plant energy and biomass. Simmons et al. (1982) and Benbelkacem et al. (1984) found that high tillering lines tended to have a high tiller mortality and an increased lodging potential due to smaller diameter of stems. The capacity to produce more tillers than usually survive is a primitive trait. It may have advantages under conditions where the plant is exposed to environmental conditions as insect attack that reduce tillering or kill some tillers but it has little relevance in modern agriculture with improved measures of crop husbandry and assured plant protection. It is in this context that the breeders must consider designing a plant that is more economical in producing tillers but more efficient in ensuring their survival. It seems more promising to select those plants with relatively fewer tillers, most of which would survive to produce grains. This is not only likely to reduce intraplant competition but would also result in better ear growth in early stages.

It may be pertinent here to examine the relationships of different yield components and related characters that may possibly combine in a breeding programme to give a desired genotype. The main yield contributing characters in RAJ 2525, apart from biomass and harvest index, are the number of effective tillers and kernel weight. Maximum tiller production in this variety, though highest among those studied here, is moderate viewed in the light of literature (Chaturvedi et al. 1981). In spite of the large loss of biomass in the form of tiller mortality, this variety manages to secure the top yield rank because of its high harvest index which is not the highest possible and has room for further increase. The death of young tillers in this case may be explained by insufficient exploitation of biomass towards grain producton. It is this kind of character association that offers the greatest scope to further the yield by improving it for low tiller mortality. Selection pressure to improve tiller survival in a segregating population in favour of recombinants with the character association comparable to RAJ 2525 is likely to reflect itself in further improvement of harvest index, which, in turn, will positively effect grain yield.

RAJ 2773 ranks as high as RAJ 2525 (Table 1) for maximum tiller production, tiller mortality and number of effective tillers, but yields significantly lower because of its lower biomass and its poor capacity to partition which is reflected in its lower harvest index. Recombinants with the character association like that of RAJ 2773, thus, do not provide good material for a breeder for increasing productivity by improving tiller survival. Because of its poor harvest index such a recombinant is not likely to be able to convert fully the available biomass into grains.

UP 3005 yields as high as RAJ 2525 because of its high harvest index and high biomass. Another main component contributing towards high yield is its high kernel weight. This variety is poorer for peak tiller production and their survival and hence for number of effective tillers also. The scope for selection for tiller survival in recombinants with such a pattern of character association is narrow because of the poor capacity to produce tillers at peak periods. Even if such a recombinant could exploit the biomass most efficiently, allowing minimum loss, the number of effective tillers is not likely to reach optimum.

Biomass with respect to PBW 125 is not being fully exploited (Table 3) because of its poor harvest index. The yield is thus being mostly contributed by effective tillers and grain weight per spike which also combines grain number. During the course of selection, such recombinants do not offer much scope for yield improvement through tiller survival because of very low production of tillers at peak periods. Similarly, in the genotypes with a pattern of character association like that of HD 2329, there is little scope for improving yield because of the reasons applicable to PBW 125 and UP 3005.

In this context it is relevant to consider the optimum number of tillers. A plant should produce only as many tillers with efficient translocation to form grains without allowing any tiller to go unproductive. The present analysis suggests that ideally that stage is reached when the grain yield shows a strong positive correlation to effective tiller number and harvest index and a strong negative correlation to tiller mortality. This would indicate that biomass and harvest index are being effectively exploited to overcome mortality. It may be pointed out here that no information on the genetic behaviour of tiller survival in wheat is available.

The strategy for further increasing the yield in wheat under optimal conditions of crop husbandry should, therefore, be to select for moderate tiller production at peak periods while maintaining a high harvest index.

Methodology

A slight modification in the standard pedigree method of selection may be advantageously applied to achieve the above objective. The steps are outlined below (Fig. 2):

1. Choose the desirable parents and make crosses.
2. Grow F_1 under competition. Bulk harvest at maturity.
3. Grow some of the F_2 under competition and the remainder spaced at 8–10 cm. Evaluate for peak tiller production and tiller survival under competitive conditions and mark such

crosses which exhibit low tiller mortality. Of the selected crosses, examine the spaced single plants for moderate tillering and high tiller survival. Select desirable plants. Other desirable characters may also be taken into consideration.
4. Grow some of the plant-to-line F_3 under competition and the remainder spaced at 8–10 cm. Evaluate the tiller mortality under competition and in spaced plants. Select the desirable recombinants (for other characters also) from the spaced population to carry on to further generations. This practice may be carried on till homozygosity is achieved after which yield tests may be conducted.

Evaluating lines out of the same plant at two densities and selecting from the spaced one ensures a high probability that the right genotypes are being isolated. Though the proposed method is not fool-proof, it appears to be a marked improvement over the one in vogue, especially selecting for low mortality.

A distinct advantage of this modified procedure is that it enables a breeder to test for productive tiller survival under competition in early generations, without allowing the same to be delayed until preliminary yield tests as is the present practice. It also enables a breeder to reject the crosses that show poor tiller survival in the F_2 itself. This lessens the burden of the breeder as regards land, labour and other resources. This procedure also allows other desirable characters to be taken care of simultaneously so that a special programme for tiller survival may not necessarily be taken up.

This modified methodology of selection may also be effectively applicable to other grain crops like barley, triticale and oats.

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