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Frequency Distribution of Yield Components as an Index of Stability in Wheat at Different Levels of Water Availability

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The mother shoot ear characters of wheat observed in pot culture or in controlled environment have usually been extended to determine source and sink relationship under field conditions. The ear characters of mother shoot were compared with those observed in a population through frequency distribution analysis. Four cultivars each of *Triticum aestivum, T. durum* and triticale were used in three treatments, viz., irrigated, pre-sowing irrigated and unirrigated. In all cases 250 plants/m^2 were maintained but shoots of even half of these did not show ear characteristics similar to the mother shoot, suggesting that both the mother shoot and tillers experience competition in population. The stability in frequency distribution of ear weight, grain weight/ear and grain number/ear was in the order of *T. aestivum*>*T. durum*>triticale. However, there were cultivar differences and some cultivars with greater stability were identified. Phenotypic features of these cultivars are described.

Keywords: Yield components, Stability under water stress, Wheat, Water availability

Introduction

Extensive studies on physiological analysis of yield in wheat have emphasized the importance of yield components (Asana 1975, Evans et al. 1975, Austin et al. 1980, Sinha & Aggarwal 1981). In most instances the compensatory behaviour of various yield components such as the number of spikelets/spike, number of grains/spikelet and grain weight have been studied in pots under controlled environmental conditions or in natural environment (Rawson 1970, Asana 1975). These studies do not necessarily reflect upon the competition effects of a population which a crop normally experiences under field conditions. Indeed as pointed out by Donald (1968) there are very few studies on the competition behaviour of various varieties of wheat. In a comparative study involving one variety each of tall, medium and dwarf wheat, it was observed that the frequency distribution of yield components in a field grown crop was poorly related to the yield components obtained in pot grown plants (Sinha unpublished). Since the competitive behaviour is likely to be strongly influenced by water availability and genetic variability, the present study was undertaken in twelve cultivars of *T. aestivum*, *T. durum* and triticale.

Materials and Methods

Four cultivars each of *Triticum aestivum*, *Triticum durum* and triticale were grown in a randomized block design in field under three different irrigation levels (1) no irrigation (2) one (pre-sowing) irrigation, and (3) 5 irrigations at recommended stages of crown-root initiation, jointing, booting, flowering and grain filling (henceforth referred as I_0, I_1, I_2 respectively).

The cultivars were:

T. aestivum—NP 824, C 306, HD 2009, HD 2143
T. durum—MG 191-24-1, MG 180-9, MG 413-1, MG 120-1
Triticale—DTS 138, DTS 47-1, DTS 205, DTS 141.

Sowing of cultivars under I_0 treatment was done 25 days earlier than for I_1 and I_2 (Nov 15, 1977) in order to ensure adequate germination on conserved moisture. Fertilizers in proportion of 75 N, 60 P and 60 K were given as one single basal dose. The distance between lines was 20 cm and the plants in each line were 2 cm apart. The total rainfall for the entire crop season was 9 cm.

At maturity, ears from 1 m length of plants were harvested from each of the replicates. All ears were weighed individually. Later these were thrashed to obtain grains which were counted and weighed. Ears of 5 mother shoots which were tagged 15 days after sowing were processed similarly. The distribution for ear weight, grain weight and grain number for all varieties was analysed. Majority cultivars followed 'Type 1' distribution of Pearson's system of frequency curves (Elderton & Johnson 1969).

Results

Yield components of the mother shoot

The mother shoots in *T. aestivum*, *T. durum* and triticale had a mean of 22, 19 and 26 spikelets per spike. In all the three groups there was a reduction in the number of spikelets in I_1 and I_0 treatments (table 1) but it was least in triticale and was followed by durum and aestivum wheats.

The maximum ear weight and grain weight/ear were observed in I_2 treatment in triticale. However, there was greater reduction in both ear weight and grain weight/ear in triticale, whereas it was minimum in *T. aestivum* followed by *T. durum* (table 1). A similar effect was observed in the number of grains/ear. The average weight of a grain was not significantly different in different groups and treatments.

Average yield components of the population

The average ear weight in I_2 treatment was 2.01, 2.41 and 2.11 g in aestivum, durum and triticale, respectively (table 2), thus showing a decrease of 43, 33 and 56% respectively as compared to the mother shoot. In I_0 treatment the average ear weights were 1.77 g, 1.54 g and 1.22 g in aestivum, durum and triticale respectively. Therefore, reduction from the mother shoots was 48%, 55% and 63% in these groups. It is then clear that though the triticales have the maximum ear weight potential of the mother shoot but in a population they loose more than both aestivum and durum. With a reduction in availability of water they loose still more. Comparatively, aestivum decrease the least.

The grain weight/ear was reduced more in all the treatments in population as compared to the grain weight of the mother shoot (tables 1–2). The reduction was 43, 31 and 55% in I_1 and 45, 49 and 61% in I_0 treatment in aestivum, durum and triticale respectively. Once again it is clear that in a population there is a loss in grain weight/ear and it occurs more in triticales than in either aestivum or durums.

Table 1 *Effect of water stress on yield components of mother shoots of* T. aestivum, T. durum *and triticale (numbers in parenthesis are the percentages over irrigated taken as 100)*

Group	Yield component														
	Spikelets/ear			Weight/ear, g			Grain wt/ear, g			Grain number/ear			1-Grain wt., mg.		
	I_0	I_1	I_2	I_0	I_1	I_2	I_0	I_1	I_2	I_0	I_1	I_2	I_0	I_1	I_2
T. aestivum	17 (77)	18 (82)	22 (100)	3.42 (98)	2.95 (85)	3.49 (100)	2.51 (100)	2.05 (82)	2.51 (100)	56 (98)	48 (84)	57 (100)	45 (102)	43 (98)	44 (100)
T. durum	15 (79)	16 (84)	19 (100)	3.42 (94)	3.36 (92)	3.64 (100)	2.29 (90)	2.33 (91)	2.56 (100)	42 (84)	43 (86)	50 (100)	55 (108)	54 (106)	51 (100)
Triticale	21 (81)	23 (89)	26 (100)	3.26 (68)	3.84 (80)	4.79 (100)	2.35 (70)	2.77 (83)	3.35 (100)	52 (75)	58 (84)	69 (100)	45 (92)	48 (98)	49 (100)
L.S.D. Group × Irrigation		0.70			0.31			0.20			0.6			N.S.	
L.S.D. Group × Group		2.1			0.70			0.50			10.5			N.S.	

I_0=Unirrigated; I_1=Presowing irrigation; I_2=Irrigated on 5 occasions

Table 2 *Effect of water stress on yield components of* T. aestivum, T. durum *and triticale in a population (numbers in parenthesis are the percentages over irrigated taken as 100)*

Group	Yield component														
	Weight/ear, (g)			Grain Weight/ear, (g)			Grain number/ear			1-Grain wt., (mg)			Number of ears/m²		
	I_0	I_1	I_2	I_0	I_1	I_2	I_0	I_1	I_2	I_0	I_1	I_2	I_0	I_1	I_2
T. aestivum	1.77	1.80	2.01	1.40	1.23	1.43	35	33	40	40	37	36	232	471	629
	(88)	(90)	(100)	(98)	(86)	(100)	(88)	(83)	(100)	(111)	(103)	(100)	(37)	(75)	(100)
T. durum	1.54	1.95	2.41	1.18	1.31	1.82	27	28	37	44	47	49	193	347	590
	(64)	(81)	(100)	(65)	(72)	(100)	(72)	(76)	(100)	(90)	(96)	(100)	(33)	(59)	(100)
Triticale	1.22	1.66	2.11	0.92	1.16	1.53	24	30	38	38	39	40	189	318	548
	(58)	(79)	(100)	(60)	(76)	(100)	(63)	(79)	(100)	(95)	(98)	(100)	(34)	(58)	(100)
L.S.D. Group × Irrigation		0.05			0.45			12			N.S.			43	
L.S.D. Group × Group		0.12			0.18			N.S.			N.S.			56	

I_0=Unirrigated; I_1=Presowing irrigation only; I_2=Irrigated on 5 occasions

The average number of grains/ear was reduced in all the groups in a population (table 2). The maximum reduction of 37% occurred in triticale and the reduction in aestivums and durums was 12–28%. Thus, a large part of reduction in grain weight/ear could be due to reduction in the number of grains/ear.

The individual grain weight in the population was lower compared to the mother shoots in all the three treatments of each group indicating that most ears did not reach the potential of mother shoots. Therefore, in conclusion among the three major yield components—number of grains/ear, grain weight/ear and individual grain weight, the last one was affected the least irrespective of the group.

Frequency distribution: Before describing the results of frequency distribution, it may be important to point out that 250 plants/m^2 were maintained after thinning in all the varieties and treatments. It was only among aestivums that 232 ears/m^2 were harvested in I_0 treatment (table 2). Two varieties, HD 2009 and HD 2143 did give a harvest of 252 and 270 ear/m^2 each. However, in other groups, namely, durums and triticales, the number of ears/m^2 were less than 200. In I_2 treatment there were 548–629 ears/m^2 as against 318–471 in I_1.

Weight/ear: Figure 1A describes the distribution of this character for aestivum, durum and triticale. In aestivum, there was a large percentage of ears ranging from 1.5–2.0 g in weight irrespective of the treatment. The frequency distributions in this group were fairly similar to each other. The maximum ear weight class in irrigated durum was around 2.4 g, it got reduced slightly in I_1 but in I_0 it was severely reduced (1.4 g). In triticale the ears with lower weight greatly increased with limited water availability.

Grain weight/ear: In *T. aestivum* the peak for grain weight per ear ranged between 1.5 to 2.0 g in all the treatment and the curves for different treatments by and large overlapped each other (figure 1B). In comparison, there was a distinct shift in grain weight in *T. durum* with decreasing water availability. The most severe effect was observed in triticale where the percentage of ears with lower grain weight greatly increased under stress.

Grain number/ear: The peak for the number of grains/ear was at 43 in I_2 treatment in *T. aestivum* (figure 1). It shifted to 36 grains/ear in I_1 and I_2 treatments but retained gradual slopes on both the sides. In *T. durum* the ears with 39 grains each occurred most frequently in I_2 but shifted to 26–27 grains/ear in I_1 and I_0 treatments. However, the peak was very broad indicating a larger number of ears with medium number of grains/ear. In triticale, the peak shifted from 34 grains/ear in I_2 to 26–27 grains/ear in I_1 and I_0 treatments. A majority of ears contained 10–35 grains per ear as against the maximum of 86 grains/ear.

Frequency distribution at the varietal level: Among the four varieties of *T. aestivum*, there were differences in frequency distributions for all the components. In ear weight, minimum change occurred in NP 824 followed by C 306 but there was a marked shift in HD 2009 (figure 2A). However, most varieties retained their frequency characteristic in grain weight/ear at all the three levels of water availability (figure 2B). In grain number there was little shift towards lesser number of grains/ear in NP 824 and HD 2143, but a marked shift occurred in HD 2009 (figure 2C). On the basis of grain weight/ear, which is a product of the number of grains/ear and the individual grain weight, C 306 and HD 2009 appear to be most stable and are followed by NP 824 and HD 2143. In fact this result does support the data obtained on yield on a unit area basis at different levels of water availability (Sinha et al. unpublished data).

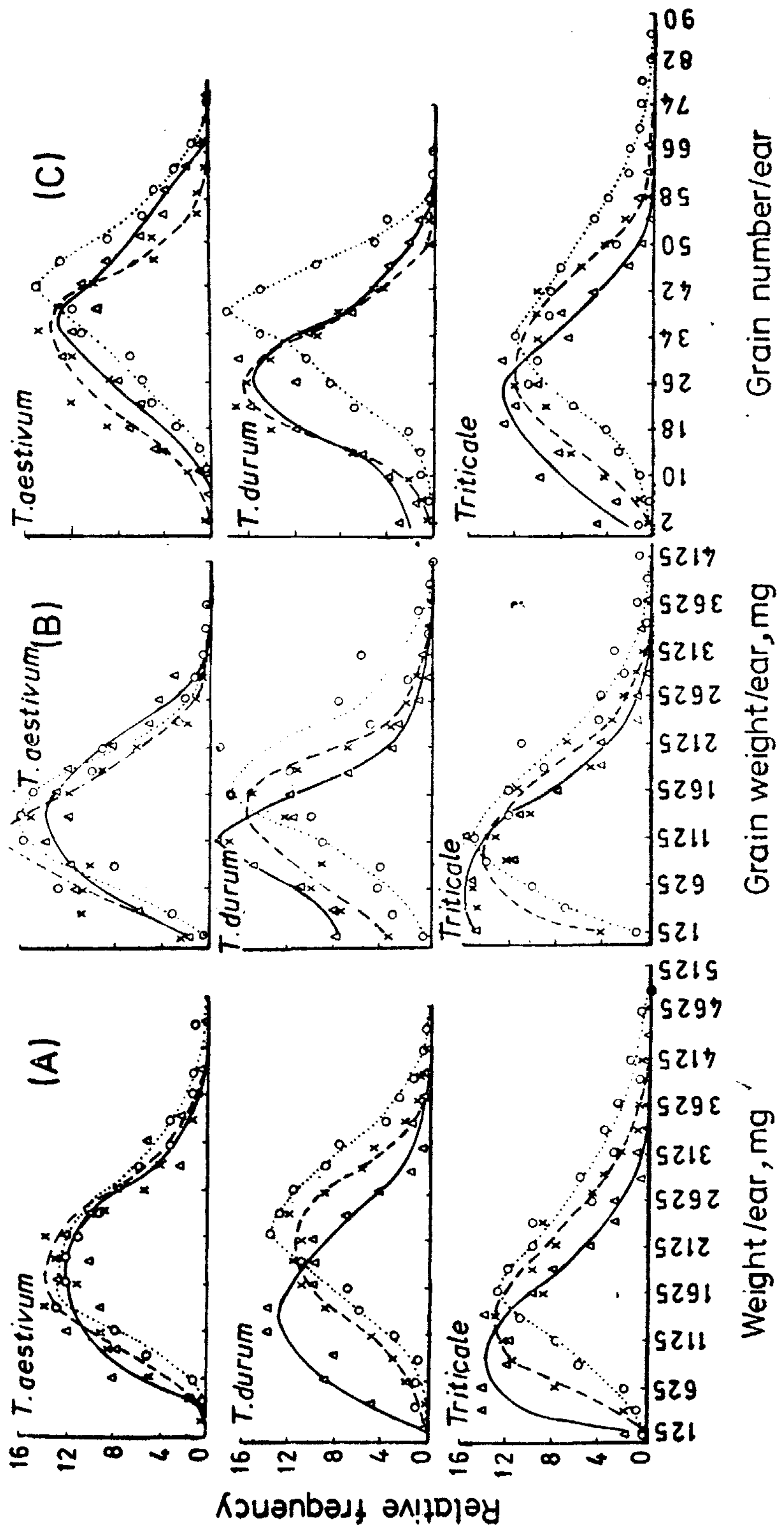

Figure 1 Frequency distribution curves for ear characters of *T. aestivum*, *T. durum* and triticale under different levels of water availability. (A) Weight/ear, (B) Grain weight/ear, (C) grain number/ear. ——I_0; — — —I_1; ...I_2

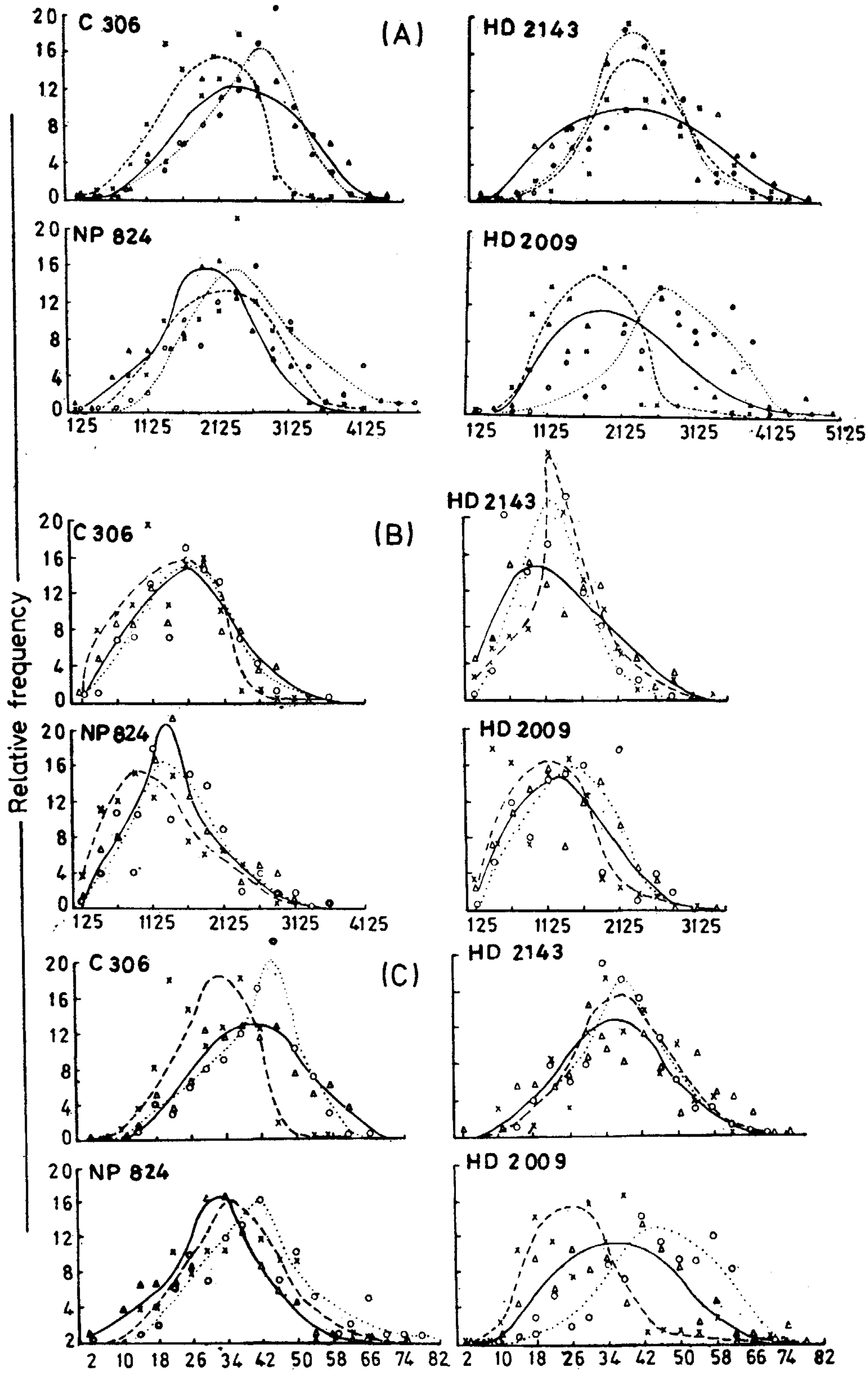

Figure 2 Frequency distribution curves for ear characteristics of four cultivars of *T. aestivum* at differet levels of water availability. (A) Weight/ear, mg; (B) grain weight/ear, mg; (C) Grain number/ear

Among the durum wheats all the four varieties showed a shift in frequency distribution towards lower weight/ear (figure 3A). The varieties MG 191-24-1 and MG 413-1 showed the maximum shift. In grain weight/ear the maximum stability was shown by MG 180-9 which had sharp peaks at all the levels of water availability (figure 3B). All the other three varieties showed a considerable shift, the maximum being in MG 191-24-1 followed by MG 413-1. In grain number/ear, the frequency distribution remained similar in all the three treatments in MG 413-1, whereas the predominance of ears containing fewer grains increased in lower water availability in MG 120-1 and MG 180-9 (figure 3C). Surprisingly in the variety MG 191-24-1, the shift in the number of grains/ear occurred towards the higher number at I_1 but the peak shifted towards the fewer number of grains in I_0 treatment.

In triticale, there was a well spread distribution in ear weight at I_2 in DTS 138 and DTS 47-1 but there was a marked wide peak in DTS 205-1 and DTS 141 (figure 4A). However, under stress a very sharp shift towards lower weight occurred in all varieties except DTS 47-1. In DTS 205-4-1 most of the ears were of very low weight. A similar effect was observed in grain weight/ear and grain number/ear (figure 4B). Thus it would appear that the loss in grain weight/ear could be due to a sharp decrease in grain number/ear.

Discussion

In most physiological investigations the ear characters of mother shoot have been used to determine the source-sink relationship as well as yield variation (Asana 1975, Evans et al. 1975). In fact the stability of yield of the mother shoot made Donald (1968) and Asana (1975) to suggest breeding for single culm genotypes in wheat and barley. Accordingly the yield characteristics of mother shoot are considered important in breeding for yield. In plants grown in pots or well spaced in the field, the yield differences between the mother shoot and tillers up to 4th or 5th are insignificant (Jain et al. 1973). Furthermore, our recent studies have shown that there is no significant difference in the number of spikelets differentiated in mother shoot and first few tillers. However, when the frequency distribution of ear components of tall, medium and dwarf wheats under irrigated conditions was studied, the expected number of ears with mother shoot characteristics was not observed (Sinha, unpublished). Thus it appears that in a population, the behaviour of even the mother shoot is affected and the expected yield contributing characters are not retained. In the present study an effort was made to compare the behaviour of 12 genotypes belonging to *T. aestivum*, *T. durum* and triticale in respect of their frequency distributions in a population.

In the first place, 629, 590 and 548 ears/m^2 were harvested in I_2 treatment in *T. aestivum*, *T. durum* and triticale respectively. This number was reduced to 471, 347 and 318 ears/m^2 in I_1 and to 232, 193 and 189 ears/m^2 in I_0 treatment in these groups respectively. Considering the fact that 250 seedlings/m^2 were retained after thinning, it is obvious that approximately 2 tillers in I_2 and one in I_1 besides the mother shoot were formed per plant. Since there is no decrease in the productivity of tillers up to the 4th or 5th tiller (Jain et al. 1973), it would be expected that all the ears should have had the same productivity. Assuming that competition among various shoots, including the mother shoot and tillers, would adversely influence the development of ear, one would still expect at least 250 mother shoots of the same capacity. The frequency distribution of the ear weight, grain weight/ear and the number of

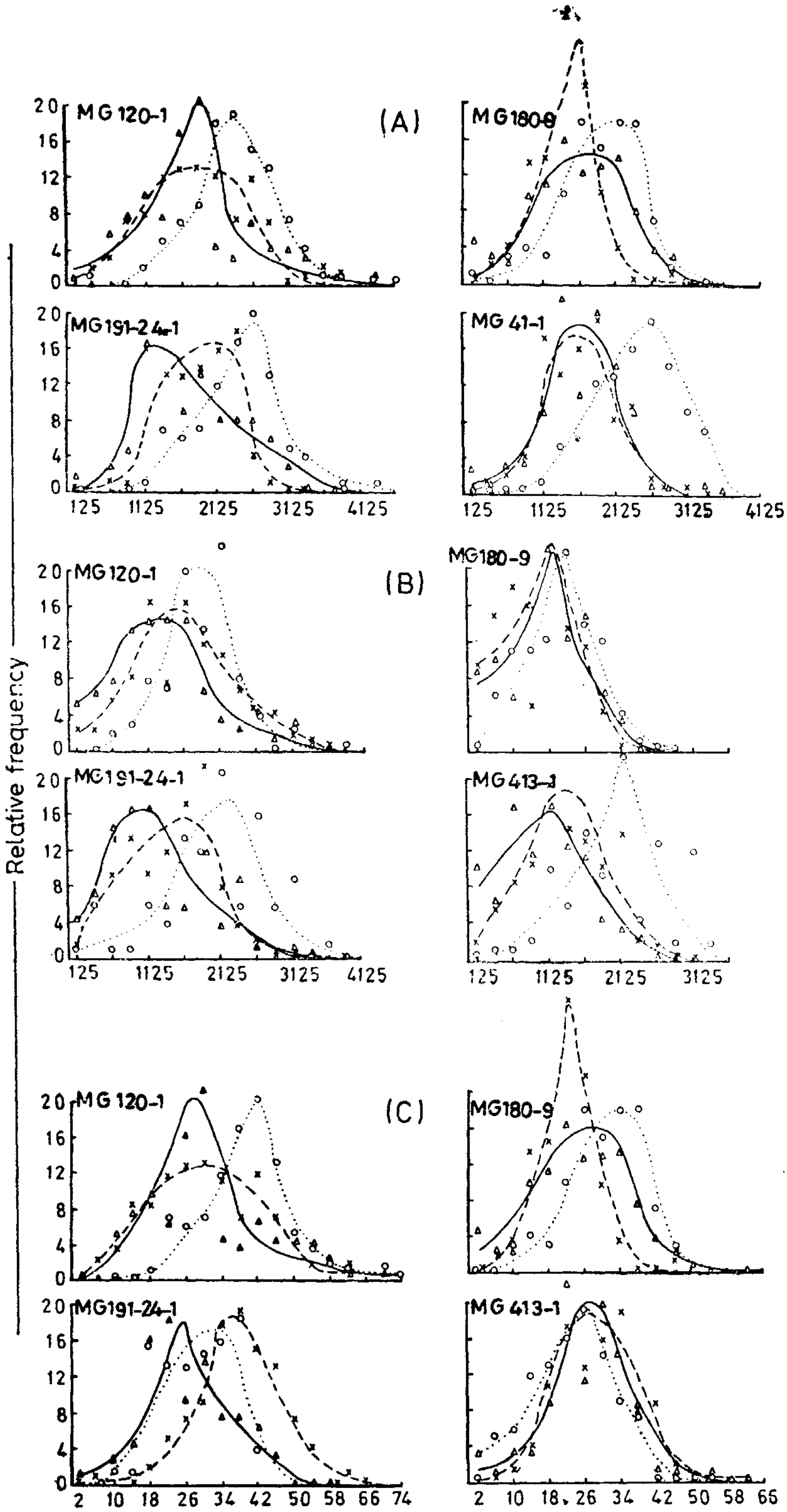

Figure 3 Frequency distribution curves for ear characteristics of four cultivars of *T. durum* at different levels of water availability. (A) weight/ear, (B) grain weight/ear, (C) grain number/ear.
______I_0; — — —I_1; ...I_2

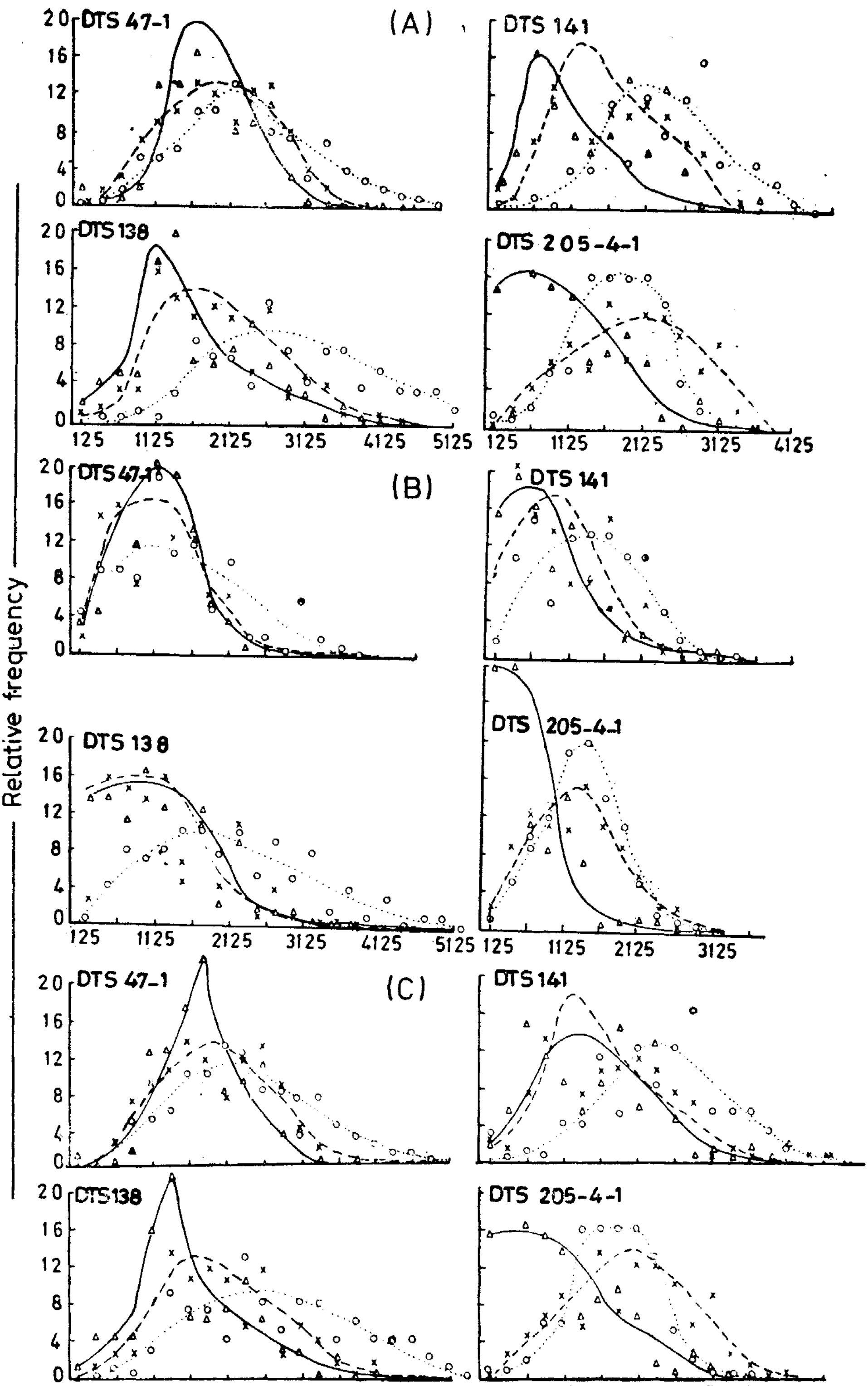

Figure 4 Frequency distribution curves for ear characteristics of four cultivars of triticale at different levels of water availability. (A) Weight/ear, (B) grain weight/ear, (C) grain number/ear.
——— I_0; — — —I_1; ...I_2

grains/ear in any of the groups or their varieties did not fulfil this expectation. It was not so even when the total number of ears/m^2 harvested was less than the number of plants/m^2. The obvious conclusion is that even the mother shoots experience competition which results in lowering their ear weight and other characteristics. Therefore, will the monoculm types be able to perform better as suggested by Donald (1968) and Asana (1968) ?

Having known that irrespective of tillering the competition among shoots would lead to reduction in yielding capacity of spikes, it is worth considering as to the stage when this competition is most effective. Sinha and Aggarwal (1980) have described the stages of competition in the phenology of wheat. Spike differentiation in most cultivars of wheat is initiated around 26 days after sowing. Tillers already make their appearance at this stage, and also get differentiated by 35th day (Aggarwal et al., unpublished data). However, at this time more or less equal number of spikelets per spike are differentiated, though at the time of ear emergence there are fewer fertile spikelets per spike. Thus, it appears that it is during this period, between spikelet formation and spike emergence that the adverse effect operates. Even the mother shoots do not escape these effects.

If we consider that production of a majority of spikes of the same size in a population is an index of stability, then it would appear from the present data that stability to water stress was in the following order *T. aestivum*, *T. durum* and triticale. However, within each group there were some varieties which had greater stability than others. For example, among aestivums, C 306 and HD 2009 were more stable. Among *T. durum* and triticale, MG 180-9 and DTS 47-1 respectively showed greater stability. It may, therefore, be important to ascertain whether all these varieties have any common characteristics. Spreading habit in seedling stage, narrow and small leaves with tillering habit are some of the characteristics all these varieties share. However, it is a question whether these characteristics are in any way related to stability. This needs further detailed studies.

The present study leads us to some simple and yet vital conclusion, which can be stated as follows:

The behaviour of ear characteristics of plants grown in a population is quite different than of isolated plants shoots. Therefore, the source-sink studies largely based on mother shoot in the absence of competition may be of limited value from the point of crop improvement.

Since there is only a small difference in the number of spikelets initiated but there is a reduction in the yielding capacity of the spike in a competitive environment, it is important that we make efforts to understand it more.

Stability in ear characteristics is an important factor in determining yielding capacity of a cultivar. Methods need to be developed to study this in a large number of genotypes.

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