https://doi.org/10.29321/MAJ.10.A03484

Studies on the Physiology of Heterosis
Physiological and Biochemical advantages in Hybrid Bajra-1 (Pearl Millet) as compared to its non-heterotic parents

by

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Introduction: Eventhough a great deal of information has been accumulated about the phenomenon of heterosis, we are sill unable to define exactly why a hybrid grows better than the parents from which it comes. The cause may be physiological and the hybrid may function effectively with increased metabolic efficiency. The specific physiological processes which contribute to the vigour in the hybrid may be numerous and complex rather than single and simple and they may not be the same for all examples of hybrid vigour. The operational descriptions of heterosis have not yet been well presented.

Review of Literature: Miller and Johnson quoted by Whaley *et al.* (1950) tried to localise the cause of hybrid vigour by studying the chlorophyll concentration in the hybrid and the selfed lines of corn. They found in corn that there was not always a higher concentration of chlorophyll in the hybrids. Milfin and Hageman (1966) studied the chloroplast activities in the hybrid corn and reported only intermediate activity. Ashby (1937) studied the rate of photosynthesis in hybrids and its parents and found that the leaves of hybrids were not more efficient in photosynthesis than the leaves of parent plants. However a marked hybrid superiority in photosynthetic CO_2 fixation by young maize hybrids and Barley hybrids was observed by Sarkissian (1963).

A study of enzyme system acting on important metabolic processes will be helpful in discussing the concept of heterosis. The data of Hageman (1968) indicated that nitrate reductase activity in maize was controlled genetically and heterotic effects were not apparent in the activity of this enzyme. The hybird was intermediate between the parental values. Whaley (1952) reported greater index of catalase activity in the shoot tips of maize hybrids, than either of the parents.

Materials and Methods: Hybrid bajra-1 and its parents Bil.3 B and Tf 23-A were raised under uniform field conditions in randomised block design. Periodical observations were made for all growth characters. The total chlorophyll content of third and fourth leaf from the top of the plant was estimated by spectrophotometric method (A. O. A. C. 1960), at

+Part of the thesis submitted to University of Madras for M.Sc. (Ag.) degree.

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four stages of the crop namely seedling, tillering, floweting and harvesting. The phytosynthetic rates of foliage at four stages were estimated by manometric method (Umbreit *et al.* 1964). The nitrate reductase activity was determined by the method of Ekerson (192 ') in the foliage and the catalase activity was estimated by the method improved by Gopalachari (1963)

Results and Discussions : The hybrid bajra-1 exhibited its superiority in respect of total chlorophyll content of the foliage at all the four stages studied (Table 1).

TABLE 1. *Total chlorophyll content of hybrid and its parents expressed as mg/g of leaf tissue*

Parents & Hybrids	Seedling 20	Tillering 40	Flowering 60	Harvesting 80	Stages days
Bil 3 B	0.822	2.282	2 380	2 693	
Tf 23 A	1.328	2.024	3.466	3.133	
HB 1	1.466	2.422	3.983	3.572	

Generally chlorophyll content of foliage increased upto flowering stage after which a slight decrease was noticed. There was a clear evidence that HB1 showed a definite heterosis for chlorophyll concentration. Many of the economic factors have been correlated with the concentration of chlorophyll.

The male parent Bil 3 B showed better photosynthetic efficiency than the seed parent Tf 23 A, while the HB1 was distincly superior to both the parents.

TABLE 2. *Photosynthetic rates of leaves of hybrid and its parents expressed as μl of O_2 released per hour per g of dry weight of leaves*

Parents & Hybrid	Seedling 20	Tillering 40	Flowering 60	Harvesting 80	Stages days
Bil 3 B	3387	4444	9544	8073	
Tf 23 A	3542	3792	9019	6508	
HB 1	4560	6529	9932	8243	

The photosynthetic rate was maximum at the flowering stage of the crop. Marked superiority in photosynthetic rate was reported in hybrid maize and barley by Sarkissian (1963) and others. They were also of opinion that stimulation of photosynthetic rate in the hybrid were generally associated with hybrid vigour, which was true here.

Hybrid bajra 1 produced larger number of tillers, resulting in increased number of leaves per plant and so naturally the leaf area was greater in the hybird than the parents, Bil 3 B and Tf 23 A. The leaf area per plant observed at three stages showed a distinct heterotic effect (Table 3).

TABLE 3. *Leaf area per plant at four stages expressed in sq. cm per plan*

Parents & Hybrids	Tillering 40	Flowering 60	Harvesting 80	Stages days
Bil 3 B	972	2911	2724	
Tf 23 A	748	2579	3482	
HB 1	1223	4579	4714	
F value significance		Yes	Yes	Yes
C.D. at 5% level		147.61	1606.02	759.1

HB 1 hybrid not only gained an advantage in the photosynthetic efficiency of leaves over its parents but also in its photosynthetic surface. These two main physiological advantages may be the important causes for the greater growth rate and greater dry matter accumulation in the hybrid. The greater leaf area is one of the manifestations of heterosis or it may be the causal agent for it.

The nitrate reductase activity of foliage estimated at four stages showed heterotic levels at harvesting stage of the crop.

TABLE 4. *Nitrate reductase activity (mg nitrate N/100 g of leaf tissue) in the hybrid and the parents at the four stages of growth*

Parents & Hybrids	Seediing 20	Tillering 40	Flowering 60	Harvesting 80	Stages days
Bil 3 B	0.900	0.998	0.996	0.860	
Tf 23 A	0.868	0.890	0.988	0.824	
HB 1	0.956	0.928	0.994	0.926	

This finding agreed with Schreder *et al.* (1968) that more level of nitrate reductase was seen both in hybrids and inbreds during reproductive phase. It was also seen later that the protein content of the grain increased in the hybrid which can be related to high nitrate reductase activity during harvesting stage as observed by Hageman *et al.* (1967) and Leng *et al.* (1962).

The catalase activity which is largely associated with active meristematic growth (Whaley, 1952) also showed heterotic levels in HB 1 on 20th day, 60th day and 80th day.

TABLE 5. *Catalase activity of the foliage of hybrids and parents at four stages of growth expressed in mg of H_2O_2 released*

Parents & Hybrids	Seedling 20	Tillering 40	Flowering 60	Harvesting 80	Stages days
Bil 3 B	1.41	2.00	1.52	2.41	
Tf 23 A	1.54	1.64	1.08	2.42	
HB 1	1.91	1.50	1.66	2.93	

It was somewhat clear that in the seedling as well as flowering and harvesting stages the hybrid exhibited superiority over its parents. The greater activity of catalase may be related to the vigour of the hybrid as reported by Whaley *et al.* (1952) in hybrid maize.

Summary : An attempt was made to study certain physiological and biochemical advantages of HB 1 over its parents Bil 3 B and Tf 23 A raised under uniform field conditions. The total chlorophyll concentration in the hybrid was always higher than the parents thus showing a definite physiological advantage over the parents. As regards the photosynthetic rate the leaves of the hybirds were more efficient than the parents, indicating that HB 1 not only gained an advantage in the total photosynthetic area, because of greater number of tillers and leaves produced by the hybird plant, but also in its efficiency. This may be one of the physiological explanations for the vigour in HB 1 over its parents. At subsequent growth periods, the hybrid generally showed heterotic levels of activity of nitrate reductase and catalase especially, at the later stages of crop growth.

Acknowledgment : The senior author wish to acknowledge the award of Junior Research Fellowship by Indian Council of Agricultural Research during the course of this study.

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