The present work was undertaken to unfold some of the major metabolic events during reproductive differentiation in five hybrids and parents of *Pennisetum typhoides* S & H. An attempt was made to correlate the changes in these major metabolic processes involved in heterosis manifestation which was ultimately reflected in efficient growth, development and yield in hybrids when compared to the respective inbreds. The investigation was carried out in following three experiments.

**Experiment - I :** Study of growth and yield contributing characters of hybrids and their parents.

Seeds of following biotypes of bajra (*Pennisetum typhoides* S & H) hybrids and their parents were procured from Millet Specialist, Gujarat Agricultural University, Jamnagar.

1. 126 D2A x J 1270 (Hybrid)
2. 5071 A x J 41 (Hybrid)
3. 5071 A x J 104 (Hybrid)
4. 5071 A x K-559-85 (Hybrid)
5. 126 D2A x J 1399 (Hybrid)
Each type of seed was sown in the field. The plot size was 2.5 x 5 meters. The distance between two rows was maintained 25 cms while the distance between two plants was kept 15 cms. Before sowing, the field was thoroughly ploughed and was enriched with 250 gms diammonium phosphate (DAP) per plot with subsequent irrigation. 250 gms urea per plot was given twice during the life span of the crop and irrigation was practised to optimise the growth, development and yield of the plants.

From 20th day onwards following growth criteria were noted selecting 10 individual plants at random at weekly intervals upto maturity.

(A) Growth criteria

i. Plant height

ii. Number of tillers

iii. Number of leaves

iv. Number of internodes
(B) Fresh weight and dry weight

For the study of growth habits three plants from each variety were randomly selected at weekly interval and uprooted. Fresh weight of the following organs were recorded separately for each plant.

i. Whole plant
ii. Root
iii. Stem
iv. Leaves

After recording the fresh weights, all the above organs were placed in paper bags and were transferred in an oven to dry them. Dry weights of all the above mentioned organs were recorded.

(C) Flowering data

With the onset of flowering, number of cobs in flowering was recorded every day in all the plants. Anthesis was also recorded and number of cobs in flowering and anthesis per 100 plants was calculated.

(D) Harvest data

When the crop was ready for harvest 10 plants of average size were selected in each variety and following yield criteria were studied.
i. Number of cobs
ii. Length of the main cob
iii. Weight of cobs
iv. Number of grains
v. Weight of grains
vi. 1000 grain weight
vii. Weight of the fodder
viii. Weight of the whole plant

(A) Growth criteria

In hybrid 126 D2A x J 1270 growth characters like number of tillers and number of leaves exhibited a poor performance while in other hybrids an intermediate pattern was seen in comparison to their respective inbreds. Number of internodes was heterotic in hybrid 126 D2A x J 1399 while in other hybrids an intermediate number was discernible. Height of all hybrids revealed either a heterotic or medium performance with respect to their inbreds.

(B) Fresh weight and dry weight

The fresh weights and dry weights in all the hybrids revealed either intermediate or heterotic pattern when compared to their respective parents. Except in male J 1270 which was intermediate to hybrid and the female parent, in all the remaining crosses male parents revealed a poor
performance of fresh and dry weights as compared to the respective hybrid and female parents.

Based on the dry weights, relative growth rate (RGR), leaf weight ratio (LWR) and net assimilation rate (NAR) of all the plants were calculated.

RGR: In hybrid 126 D2A x J 1270 and 126 D2A x J 1399 mean RGR was low, while in other hybrids it was intermediate with respect to their parents. Male parents in all the crosses exhibited a lower RGR when compared to female parents.

LWR: In hybrid 5071 A x J 41 mean LWR was medium and in the rest of hybrids it was low in comparison to their respective parents. Except male K-559-85 all other male parents exhibited a low LWR when compared to female parents.

NAR: NAR was equal to its female parent in hybrid 126 D2A x J 1270 while in hybrid 5071 A x J 104 it was equal to its male parent. All other hybrids either exceeded or revealed an intermediate NAR when compared to their parents. Male parent showed a higher NAR when compared to female parents in cross 126 D2A x J 1270, 5071 A x J 41 and 5071 A x J 104 while in the remaining crosses it was lower.
(C) Flowering data

In hybrid 126 D2A x J 1270 flowering and anthesis per 100 plants was quite low, all other hybrids revealed either a medium or heterotic pattern. Flowering was also early or next to the earlier parents in all the hybrids except 126 D2A x J 1270.

(D) Harvest data

Percent heterosis in grain yield showed that hybrid 126 D2A x J 1270 was negatively heterotic (-36.84 %) while all other hybrids were positively heterotic. Various yield contributing characters like number of cobs, weight of cobs, number of grain, weight of grain etc. exhibited a poor performance in negatively heterotic hybrids when compared to its parents while in the remaining positively heterotic hybrids these characters showed either an intermediate or heterotic pattern.

Experiment - II : Biochemical analyses during reproductive differentiation in hybrids and their parents

Stages selected for biochemical analyses were as under:

i. Mature growing apex and its corresponding leaf.
ii. Reproductive apex and its corresponding leaf.
iii. Young flower bud and its corresponding leaf.
iv. Flower with unfertilized carpel and its corresponding leaf.
v. Flower with fertilized carpel and its corresponding leaf.
vi. Developing caryopsis and its corresponding leaf.
vii. Mature caryopsis and its corresponding leaf.

In the above stages following biochemical analyses were performed.

1. Ascorbic acid turnover.
2. Peroxidase activity.
3. Ascorbic acid-free radical peroxidase activity
   (AA-FR-peroxidase)
4. Catalase activity.
5. Invertase activity.
6. Protease activity.
7. RNase activity
8. DNA content.
9. RNA content.
10. Protein content.
11. Histone content.

The negatively heterotic hybrid (126 D2A x J 1270) had a low RGR and NAR. Concomitant with these the metabolic status of this hybrid was also low during reproductive differentiation when compared to its parents. It exhibited a
low value of ascorbic acid utilization, peroxidase, AA-FL-peroxidase, RNA and protein. RNase exhibited a high value especially during first three stages during reproductive differentiation. However, ascorbic acid, ascorbigen and DNA content in flower stages revealed a heterotic nature. These results indicate a lack of proper balance in various metabolites in this hybrid.

In all other positively heterotic hybrids the metabolites like ascorbic acid turnover, nucleic acids, protein, histone, some oxidative and hydrolytic enzymes favoured better synthetic efficiency during reproductive differentiation by exhibiting an intermediate pattern which is suggestive of a more balanced metabolism in heterotic hybrids.

Experiment - III : Biophysical study from seeds of F1 hybrids and their parents

F1 seeds of two highly heterotic hybrids (in grain yield- 5071 A x J 104 and 5071 A x K-559-85), as well as their parents were taken. They were crushed in 5% perchloric acid and a constant volume was made. Mn⁺⁺ content was determined employing electron spin resonance (ESR) technique. Mn⁺⁺ content in hybrid 5071 A x J 104 and 5071 A x K-559-85 was intermediate in comparison to their respective parents. This is again suggestive of a more balanced metabolic state of positively heterotic hybrids.
From the preceding study it emerges that major metabolic processes are usually intermediate in hybrids when compared to their inbreds.

CONCLUSION

Problem of heterosis has a number of biochemical and molecular genetic aspects. In these, evaluation of genome activity is important, because heterosis is directly connected with intensity and character of heterotic hybrid genotype realization within the morphogenetic systems and the analysis of these genome areas. They are closely connected with the hormone regulation of metabolism and morphogenesis of plants (Konarev, 1976).

The correlation of the nutritional substances in the yield is only indirectly connected with heterosis. The content of separate chemical components is inherited according to normal genetic principles as a polygenic character. Therefore, to obtain heterotic hybrids with the desired content of the nutritional components it is necessary to have selfed lines not only of good combining ability but also as good sources of yield quality. It is necessary to look for more efficient ways for the realization of heterosis effect in plant industry, and to use more reliable methods for evaluating lines and clones for their combining abilities, and for heterosis prognostication. This can be
achieved through knowledge of the genetic nature of heterosis and of the biochemical and physiological mechanism of its manifestation.

In this connection the present study envisages an understanding of some biochemical and biophysical levels of heterosis. It helps to understand the changes in the metabolic state (consisting of nucleic acids, ascorbic acid turnover, manganese, protein, histone and some oxidative as well as hydrolytic enzymes) during reproductive differentiation in hybrids and their parents. An attempt has been made to correlate the changes in these metabolites with growth, development and yield of hybrids and their parents. It was found that afore cited metabolic processes may play a pivotal role in manifestation of heterosis.

In case of a negatively heterotic hybrid some of the above metabolic criteria exhibited a poor performance while in positively heterotic hybrids they revealed an intermediate pattern. Thus the present investigation supports the following conception of Konarev (1976). "Existing data on hormones and biologically active compounds of vitamin type gave an opportunity to suppose that complementation of such systems on metabolic level may be one of the essential factors of heterosis". The study also encompasses the performance of ascorbic acid in cell behaviour and supports the excellent ascorbic acid-nucleic acid-protein metabolism
concept of growth and flowering" advanced by my revered teacher late Professor J. J. Chinoy (1964a, 1967a, 1967c, 1969a, 1969b). It also supports his novel concept of "heredity in terms of reaction rates and electron transport", advanced in 1970. The consistent findings that the heterotic hybrids show intermediate trend in the enzymatic activities and important metabolic reactions between their parental inbreds is significant. It is borne out that major metabolic processes as a whole tend to be limited in rate by least efficient reaction which in turn limit the overall reaction rates.

The F1 hybrids usually possess a more favourable genetic constitution and thus produce a better enzymatic balance for overall enzymatic efficiency than do either of the parents. Heterozygote has been observed to be usually intermediate in enzymatic activity which, as a matter of fact, is adequate for most of the major metabolic processes and may actually be more effective for overall metabolism.

The present investigation supports the view of Hoyse (1959), that hybrid vigor is not always the result of high rate of enzyme activities but may result from the balanced environment-genotype interaction or competition for energy and metabolites. The change in level of activity of any enzyme could alter metabolism and ultimately the final
phenotypic expression.

The present work revealed that some of the major metabolic processes, involving nucleic acid metabolism, ascorbic acid turnover, protein metabolism, manganese content as well as some oxidative and hydrolytic enzymes were in a more balanced state in the positively heterotic hybrids (as evidenced by their intermediate pattern) than in the negatively heterotic hybrid (as evidenced by their poor performance). These results supports "balanced metabolism theory" of heterosis put forth by Robbins (1952). This theory implicates that vitamins and enzymes neither in shortage nor in excess are beneficial to plant. Only in balanced form they are effective.