DISCUSSION

The present work centres round the performance strategy of the F1 hybrids and their parents. It analyses the physiological and biochemical parameters characterizing the hybrid vigor. The following important features emerge from the preceding results.

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

2. Fresh weight and dry weight in all hybrids remained either intermediate or exceeded better 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.

3. Except hybrid 126 D2A x J 1270 all the remaining hybrids exhibited an intermediate or higher number of cobs in flowering and anthesis. At the same time flowering was early or next to one of the parents in all the hybrids except in 126 D2A x J 1270 as compared to their parents.
4. In hybrid 126 D2A x J 1270 and 126 D2A x J 1399 mean relative growth rate (KGR) was low, while in other hybrids it was intermediate with respect to their parents. Male parents in all the crosses exhibited a low KGR when compared to female parents.

5. In hybrid 5071 A x J 41 mean leaf weight ratio (LWR) was intermediate 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.

6. Net assimilation rate (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.

7. Hybrid 126 D2A x J 1270 was negatively heterotic in grain yield (-36.84 %) while all other hybrids were positively heterotic in grain yield.

8. The negatively heterotic hybrid (126 D2A x J 1270) had a low KGR 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 peroxidase, AA-FR-peroxidase, RNA, ascorbic acid utilization and protein. Rβase exhibited a higher value especially during 1st three stages during reproductive differentiation. However, AA, ASG and DNA content in flower stages revealed a heterotic nature.

9. In all other positively heterotic hybrids the metabolic state i.e. ascorbic acid turnover, nucleic acids, protein, histone, 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 hybrids.

10. Mn ++ content in hybrid 5071 A x J 104 and 5071 A x K-559-85, was intermediate in comparison to their respective parents, which again points to a more balanced metabolic state of positively heterotic hybrids.

The most complex task in the practical exploitation of hybrid vigor is the choice of appropriate parental forms for obtaining cross combinations. The present study attempts to understand changes in growth, development and yield as well as some important metabolites like ascorbic acid, manganese, DNA, RNA, protein, histone and some oxidative and hydrolytic enzymes during reproductive differentiation of hybrids and their parents. It pursues the metabolic performance of a
hybrid to analyse its physiological status and takes into account the organism in its entirety to encompass the hybrid behaviour, its past, present and future.

Growth and yield analysis

In hybrid 126 D2A x J 1270 growth characters like number of tillers and leaves exhibited a poor performance. All other hybrids exhibited intermediate number of tillers between their respective parents. Other characters like height of the plant, fresh weight and dry weight in all the hybrids revealed either an intermediate or heterotic pattern. This is supported by earlier report of Golynskaya et al. (1965) that the highly heterotic maize hybrids accumulated more dry matter than the parents. Similarly Gibson and Schertz (1977) found that Sorghum hybrid had greater total dry weight than its parents throughout the growing season. Lupton (1976) observed that in four F1 hybrids of wheat, a marked heterosis for total dry weight production and leaf area index was seen. The tiller number of the hybrid was in all cases intermediate between the parents, and there were no marked differences in the proportion of tiller surviving to bear ears at harvest. In our study a similar intermediate number of tillers was observed in all the five hybrids, however, contradictory to Lupton's observation, surviving
tillers to bear productive cobs at harvest revealed a crystal clear picture. In negatively heterotic hybrid for grain yield (126 D2A x J 1270) the number of tillers were lower when compared to its parents. In markedly heterotic hybrids for grain yield (5071 A x J 104 and 5071 A x K-559-85), the surviving tillers that bear cobs was higher than their respective parents. In the remaining two heterotic hybrids for grain yield (5071 A x J 41 and 126 D2A x J 1399) the degree of heterosis was lower as compared to 5071 A x J 104 and 5071 A x 12559-35, and the number of surviving tillers bearing cobs at harvest exhibited an intermediate pattern amongst their respective parents. This is in support of Quinby and his associates (1973, 1946, 1963) who concluded that greater tillering is a manifestation of hybrid vigor in sorghum.

Except hybrid 126 D2A x J 1270 in which number of leaves was lower when compared to its parents, the remaining hybrids possessed a medium number of leaves with respect to their parents. Earlier Shull (1952) observed that hybrid plants are nearly always taller and have greater leaf area than their parental lines. However, total foliage leaf number of F1 hybrid usually is intermediate between the parental levels.

The negatively heterotic hybrid (126 D2A x J 1270) was not early flowering as compared to its parents and also exhibited a lower number of cobs during flowering and anthesis.
All the remaining, positively heterotic hybrids revealed an intermediate or higher number of cobs in flowering and anthesis. They were also early flowering or flowered next to male parents. These results support Liang (1967), Quinby and Liang (1969) who presented data to show that on an average, parents and hybrids have the same leaf number but that hybrids flowered earlier than the parents.

In the present study mean RGR was quite low in hybrid 126 D2A x J. 1270 and 126 D2A x J. 1399 while in other hybrids it was intermediate with respect to their inbreds. Similarly Voldeng and Blackman (1973) working with maize concluded that RGRs of first crosses exceeded those of parental lines from emergence to post-anthesis but are not consistently greater over the whole period. Donaldson and Blackman (1974) indicated that once the shoot emerges and becomes photosynthetically active, performance of the hybrid is primarily dependent on the NAR (Net Assimilation Rate) and LAR (Leaf Area Ratio). Hybrids 5071 A x J. 41, 5071 A x K-559-85 and 126 D2A x J. 1399 displayed either medium or higher NAR when compared to their respective parents and in the remaining two hybrids NAR was equal to one of the parents. Alvim (1960) also observed that higher NAR value indicated an increase in photosynthesis and a more rapid translocation of photosynthetates from the leaves to the stem. Higher NAR and RGR is reported in high yielding plants raised from
seeds pretreated with high temperature and ascorbic acid plus hydrogen peroxide solution (Patel, 1976).

Hybrid 126 D2A x J 1270 was negatively heterotic in grain yield (-36.84 %) while all other hybrids were positively heterotic in grain yield. This is supported by the work of Lupton (1976) who showed that all the four cosses of wheat used during his studies exhibited heterosis for grain yield in the first year of trial. Quinby (1974) is also of the view that increased grain yield is one of the universally recognized manifestation of hybrid vigor. Quinby (1973) indicated that if yield of grain and stover is the measure of performance, hybrid vigor necessarily must show differences in morphology between parents and hybrids.

Hybrid 126 D2A x J 1270 was negatively heterotic for grain yield and exhibited low value of weight of cobs at harvest while in the remaining four hybrids either a medium or heterotic pattern was revealed in comparison to their respective inbred. This is supported by the work of Quinby (1970) and Patanothai and Atkins (1971) who showed that panicles of Sorghum hybrids were heavier and larger than those of their parents, eventhough the panicles of hybrids developed in less time. Thus the general phenotypic manifestation of hybrid vigor, then, is an increase in growth rate and total size of the plant (Hageman et al. 1967). Contradictory to this, Knott (1965) examined yield of F1 from a wide
range of parental types of wheat, and although heterosis was present no hybrid exceeded the yield of the control variety Thatcher. Here the yield of the F1s followed closely to the mean parental yield. Powers (1945) observed a similar relationship between parents and the F1 in other self-pollinated crops e.g. tomatoes.

Out of five hybrids studied one was negatively heterotic in grain yield (126 D2A x J 1270) while the remaining four were positively heterotic in grain yield. The negatively heterotic hybrid exhibited poor performance in growth characters like HGR, number of leaves, number of tillers and yield contributing characters like flowering habit, number of cobs at harvest, weight of cobs etc. However, fresh weight and dry weight in this hybrid were surprisingly higher. This can be explained on the basis of water requirements. That the low productive plants had much higher water requirements was shown by Kiesselbach (1926). Positively heterotic hybrids revealed either a medium or better performance in aforecited growth, flowering and yield contributing characters.

Ascorbic acid turnover

Maximum ascorbic acid (AA) content was recorded during reproductive differentiation in all hybrids and inbreds. Michniewicz (1961) also found that AA content increased
during the course of ontogenic development and reached its maxima just before flowering.

AA content during entire reproductive differentiation however, failed to show any correlation with heterosis in growth and yield. Only in growing apices (stages I and II) negatively heterotic hybrid (126 D2A x J 1270) had a low ascorbic acid content when compared to that of its parents. This is in confirmation to Chinoy (1962) who considered the product of AA concentration and its utilization as an index of metabolic activity. Subsequently he showed a close correspondance between AA-AAU product on the one hand and the stage of differentiation, fresh weight and elongation of root and shoot of the embryo on the other. Isherwood and Mapson (1962) also suggested that the actual concentration of AA in a tissue may represent the excess formed in synthesis over that used in metabolism. There was no relationship between AA content and hybrid vigor and not the content but the turnover rate of AA is of consequence. Experimental evidence was presented to show that, under inductive photoperiod and temperature, there was a rapid upsurge in production and utilization of ascorbic acid in the shoot apex at the time of floral initiation as well as during the period of reproductive differentiation (Chinoy et al. 1957; Chinoy, 1962; Mansuri, 1965; Chinoy and Mansuri, 1966; Patel, 1967). Maximum AAU in growing apices at the
flower initiation in all hybrids and inbreds supports the above findings.

On an average AAU in all the stages and corresponding leaves during reproductive differentiation, hybrids with positively heterotic grain yield exhibited an intermediate performance between the respective two parents while the hybrid (126 D2A x J 1270) which was negatively heterotic in grain yield revealed a lower AAU value as compared to its parents. Thus AAU showed a good correlation with hybrid vigor specially in shoot, the photosynthesizing organ of the seedling (Yamazaki and Piette, 1961; Piette et al. 1961).

Thus, by increased utilization, the reductive atmosphere which is necessary for synthetic processes in plants increases and hence the active cell division and cell differentiation take place. This finding is in conformity with previous findings reported by Chinoy et al. (1969, 1970a, 1971); Tsi’tbulko (1968); Pandya (1969) and Saxena (1969).

Peroxidative oxidation of AA by way of one electron transfer, producing an intermediate free radical (MDHA) is fairly well studied (Yamazaki, 1962; Yamazaki and Piette, 1961; Piette et al. 1961). Chinoy et al. (1969a) found that the free radical content in the shoot apex slowly increased during the period of vegetative differentiation. However, at the time of transformation of the shoot apex from vegetative to reproductive phase, there is a many-fold
increase in the production of free radicals. Free radical mechanism also appeared to be the main pathway involved in the oxidation of AA by a number of enzymes viz. ascorbic acid oxidase, peroxidase, polyphenol oxidase, cytochrome oxidase etc. Haase and Dunkley (1969) found that free radical of AA peroxidised the lipids. In support to this Hills and Wilkinson (1966) observed that ascorbate promoted lipid peroxidation in the lysosomal membranes, increased the permeability of the membranes and facilitated the controlled release of enclosed hydrolytic enzymes. The activity of these hydrolytic enzymes has been correlated with the process of cell division and rapid metabolism (Edgar, 1970).

Haygood (1950) proposed that the reduced NAD/NADH may be linked to an alternate oxidative chain with peroxidase acting on AA at the terminal end, may serve as a powerful source of energy. The rate of ascorbate turnover involves the rate of electron flow augmenting ATP production and thus regulates the rate of metabolism. Not only this but function of auxin and gibberellin in growth processes of plants is supposed to be indirect by catalysing biosynthesis of ascorbic acid (Chinoy, 1966a, 1967). Khudairi (1968) showed that AA enhances the percentage germination as well as seedling growth in lettuce and concluded that AA acts as a growth hormone up to 100 ppm.

Chinoy and his co-workers (Chinoy et al. 1974) linked
a direct interaction of AA with nucleic acids. Highly reactive free radical of -AA (MDRA), with macromolecules causes semiconduction by forming charge transfer complex (CTC) in biological systems. This interaction disrupts the electronic configuration of DNA by causing the hydrogen bonds to break, and thus bringing about the separation of the two chains, exposing new sites for m-AAA synthesis which in turn would regulate the biosynthesis and rate of electron flow. The intermediate ascorbic acid turnover of hybrids in the present study is suggestive of beneficial role of a more poised metabolism in manifestation of heterosis and ultimately reflects into better growth, development and yield.

Nucleic acid metabolism

RNA, content and RNase activity exhibited an increasing trend in all hybrids and inbreds during reproductive differentiation. Maximum DNA content was recorded in growing apices (stages I and II) in all the cases after which a slight decline was discernible and was maintained in other stages. These results find further support from the work of Patel (1976) who reported a gradual rise in RNA content and steep rise in DNA content at the time of onset of flowering.

Negatively heterotic hybrid in grain yield (126 B2A x J 1270) exhibited a higher RNase activity when compared to
its inbred lines in growing apices (Stage I and II) during reproductive differentiation. This remarkably affected RNA content which registered a low level in the same hybrid when compared to its inbreds. Degradation of RNA is caused by increased activity of the enzyme RNAse during germination (Ledoux et al. 1962; Grellet et al. 1968). In the remaining positively heterotic hybrids for grain yield a reverse trend was seen. RNAse activity in growing apices (stages I and II) was lower in hybrids and simultaneously RNA content was at a higher level when compared to their respective parents. This is supported by the observation that a marked increase in DNA is associated with active cell division and increased RNA content is associated with cell enlargement (Silberger, 1953; Silberger and Skoog, 1953; Porter, 1953; Naylor et al. 1954; Jablonsky and Skoog, 1954). Evans (1959) obtained some promotion of flower formation in a late variety of *Vicia faba* by a mixture of nucleotides. Lincoln and his colleagues (1961) found that the extracts of induced *Xanthium* and sunflower plants have consistently displayed some activity when applied to vegetative *Xanthium* plants. Some fractionation of this florogenic activity has been achieved, leading Lincoln and Cunningham to rename the active principle florogenic acid.

Highly heterotic hybrids (5071 A x J 104 and 5071 A x K-559-85) exhibited a heterotic RNAse activity during flower stages associated with intermediate RNA and DNA
content where as low yielding hybrid (L2h × J 1270) exhibited a low RuAse activity associated with a low RuA content and low DNA content in apices. However, DNA content revealed a heterotic trend in the same hybrid. Sage and Yamada (1965) suggested that nucleic acid metabolism plays an important role in thermal induction of flowering. This, increase of nucleic acids during growth and differentiation is also correlated positively with protein synthesis (Murakami, 1962).

Protein metabolism (Total proteins, basic proteins or histones and protease)

Protease activity was maximum in growing apices (stages I and II). After these two stages a little decline in the activity was seen and was then maintained at the same level during flower stages. In seed stages again a slight decline was observed. With respect to this lessening pattern of protease activity, protein content exhibited an increasing trend throughout the reproductive differentiation in all hybrids and inbreds. On an average hybrids exhibited a moderate protease activity as well as protein content throughout the reproductive differentiation when compared to their respective parents. These findings are supported by the work of Penner and Ashton (1967) who
reported that in squash cotyledons, continuous breakdown of proteins is the result of increased protease activity resulting in free amino acids and amides which are then translocated and utilized for the growth of embryo axis.

In the present study the growing apices (stages I and II) during reproductive differentiation exhibited maximum histone content in all hybrids as well as inbreds. After a slight decline it was maintained constant during the remaining stages. This is supported by Patel (1976) who reported that from vegetative to reproductive differentiation protein and histone contents increased. Gifford (1963) observed that in Xanthium and Chenopodium apices during evocation exhibited a sharp decline in nuclear staining for histones and a rise in cytoplasmic staining supporting the idea of repressive action of histones. Histones are known to have a dampening effect on the template activity of DNA for the synthesis of RNA thus serving as a suppressor of certain types of protein (Allfrey and Mirsky, 1963; Allfrey et al. 1964; Huang and Bonner, 1962). On an average hybrids exhibited either medium or lower histone content when compared to their respective parents. Low level of histones in heterotic hybrids as well as better parents was found associated with higher RNA content. This finding is supported by Shah et al. (1974) who found in maize apex that there was a decrease in histone content with a parallel increase in
RNA content again supporting the repressive action of histones.

Peroxidase

A high level of peroxidase activity was reported in growing apices (stages I and II) during reproductive differentiation in all hybrids and inbreds. During flower stages a slightly declining trend was seen. In seed stages female parents again exhibited a sharp decline whereas male parents exhibited an increase in the peroxidase activity. Hybrids revealed an intermediate pattern. However 126 D2A x J 1270 which was negatively heterotic for grain yield exhibited poor peroxidase activity during reproductive differentiation when compared to its parents. Patel (1975) also observed in cumin that a higher rate of peroxidase activity in plants grown from pretreated seeds during the formation of flower bud as well as differentiation of reproductive organs as compared with that in control. Srinivasan and Rao (1971) also reported a higher peroxidase activity in the reproductive shoots than in the vegetative shoots of grapevine. Shkol'nik et al. (1961) have shown an increase in peroxidase activity at the time of flowering.

The ubiquitous occurrence of peroxidases in plant tissues and their polymorphism indicate their importance in metabolic reactions. It has been attributed many diverse functions.
McCune and Galston (1959) reported that hormone like GA_3 altered both activity and isozyme pattern of peroxidase. Baley (1963) is of the view that peroxidase is an important parameter of growth and differentiation.

Chappet and Dubouchet (1970) correlated peroxidase activity with cell elongation in wheat coleoptile. Galston and Dalberg (1954) and Siegel and Galston (1967) ascribed a significant role to peroxidase in the regulation of cell growth and differentiation. Siegel (1955) has demonstrated a broad hydrogen donor specificity of plant peroxidases. Peroxidase activity has a direct correlation with the process of cell differentiation (Laloraya et al. 1974). Its role as a key component in growth and differentiation and in IAA oxidizing system has also been stressed (McCune, 1961; Galston et al. 1968; Nazza et al. 1970; Machachova et al. 1975; Cachita-Cosma et al. 1976). Similar observations have been obtained in Sesamum by Chinoy et al. (1973).

High peroxidase activity during cell division has been reported by Chandra et al. (1973). Kenten and Han (1950) have shown that peroxidase can oxidise a number of biologically active substances like IAA, GSU, AA, NADPH and NADH and can thus modulate the redox potential of the cell. According to Dubouchet (1972) peroxidase activity reflects the physiological stage of the cell. Bhatt (1978) supported this and observed a heterotic level of peroxidase in shoots.
of different hybrids in *Sorghum*. Hybrid vigor is mainly because of high rate of cell division. Quinby (1963) attributed the vigor in *Sorghum* to higher rates of cell division than cell elongation.

However, in the present investigation peroxidase activity during reproductive differentiation in positively heterotic hybrids revealed an intermediate trend whereas in a negatively heterotic hybrid (126 D2A x J 1270) peroxidase activity exhibited a poor performance. These led us to surmise that it is not a heterotic level of peroxidase but a more balanced activity of this enzyme which is operative in heterosis manifestation in *Sennium typhoides*.

AA-FR-peroxidase

AA-FR-peroxidase activity revealed an increasing trend during entire reproductive differentiation in hybrids and inbreds. Patel (1976) reported that in cumin, the AA-FR-peroxidase activity increased during floral differentiation as well as in corresponding leaves. Similar increase has also been reported by Jaikaria (1971), Shah (1972) and Ghesani (1972). Increase in free radical signal during transformation from vegetative to reproductive stage, where intense cellular division also occurs, has been observed by Chinoy et al. (1969b, 1970, 1971).
Average AA-FR-peroxidase activity in hybrids as compared to their respective parents, during reproductive differentiation suggests a more balanced metabolic state in hybrids than in their respective parents. Chinoy et al. (1969b, 1971) found that the enhanced concentration of free radicals of AA during the period of reproductive differentiation, supply enhanced electronic energy for accelerated cell division. Peroxidase produces free radical from a diverse number of substrates (Yamazaki, 1971; Yamazaki and Yamazaki, 1973; Yamazaki et al., 1973). Yagi and Suzuki (1965) and Yagi (1972) have shown the depolymerization of a number of macromolecules by free radical mechanisms. Intermediate nature of peroxidase and AA-FR-peroxidase in hybrids when compared to their parents is suggestive of a more balanced formation of free radicals and this leads to a beneficial supply of electronic energy for accelerated cell division and is ultimately reflected in better growth and yield.

Catalase

An increasing trend was seen in catalase activity upto stage V during reproductive differentiation in all hybrids and inbreds. In seed stages (VI and VII) it remained at a lower level. All the hybrids exhibited an intermediate catalase activity between their respective inbreds. That
the catalase activity increases from vegetative shoot apex to fertilized carpel stage then it showed a continuous decline up to senescence was reported earlier by Patel (1976). Altman et al. (1966) established a positive correlation between activities of peroxidase and catalase during respiration. This increased catalase and peroxidase activity causes the breakdown of complex food reserves into simple and soluble substances which are then utilized for the growth of embryo axis. Intermediate catalase activity in hybrids in the present study is supported by the work of Backman et al. (1964) who showed that three hybrid catalase isozymes had migration rate on starch gel during electrophoresis, intermediate between their respective parental isozymes.

**Invertase**

Maximum invertase activity was recorded in growing apices (stages I and II) during reproductive differentiation of all hybrids and inbreds. During flower stages (III to V) in hybrids and male parent it was maintained at a same level while in female parent a slight decline was observed, during seed stages (VI and VII) again a slight increase was seen in all the hybrids and inbreds. On an average invertase activity in hybrids was medium between the two inbreds. Increased invertase activity during floral
differentiation in reproductive organs as well as in the leaf of cumin was reported earlier (Patel, 1976). This also finds further support from the work of Swney et al. (1970) and Nanda et al. (1971). They observed increased activity of hydrolysing and oxidative enzymes in plants under inductive photoperiod. Recently Pawzi and Mohamed (1979) showed that successive stages of floral development exhibited different sink strengths as indicated by amylase and invertase activities and carbohydrate contents in stem apices, which increased with progression of floral development. Intermediate activity in hybrid again favours that heterotic manifestation in *Pennisetum* may be a resultant of a more balanced metabolic state.

**Manganese**

The electron spin resonance (ESR) technique has furnished evidences for the function of certain transition metal ions in the catalytic turnover of enzymes (Yamazaki et al. 1968; Yamazaki, 1971; Knowles, 1972; Sawada et al. 1972).

The universal appearance of manganese in biological materials suggests its significance in living organism. However, little is known about the biological effects of this trace element. In the present investigation F1 seeds of two positively heterotic hybrids (in grain yield) and
their respective parent seeds were analysed by ESR spectrometer for detection of this trace element. In both the heterotic hybrids manganese content was moderate between their respective parents. Mn$^{++}$ reached its summit value in male parents and minima in the female. These results indicate the involvement of metabolic reactions in the accumulation of manganese during the process of grain filling.

Views regarding the hormonal control of growth in plants are diverse. It is considered that gibberellins, possess outstanding ability to reverse genetic dwarfism at the hormonal level (Phinney, 1961; Suge and Murakami, 1968; Goto, 1975). Contrary to this it has been reported that gibberellins may not be the prime factor and a number of workers believe auxin as the major hormone (Van Overbeek, 1938; Kuraishi and Muir, 1962; Phillips, 1969). It is also suggested that the gibberellin responses are mediated through their influence on auxin synthesis (Kuraishi and Muir, 1963; Andersen and Muir, 1969).

Little attention has been paid to the regulation of IAA levels by manganese, an important cofactor in the IAA oxidizing systems. Kenten (1955) and Waygood et al. (1956) proposed that manganese is involved in the mechanism of IAA oxidase. Watanabe and Suzuki (1968) reported an increase in oxygen consumption during IAA oxidation in
presence of manganese. High levels of manganese have also been shown to increase markedly the activity of IAA oxidase (Stonier et al. 1968; Fowler and Morgan, 1972; Morgan et al. 1976). Recently manganese has also been shown to play an important role in gibberellin biosynthesis (Ogura et al. 1974).

Role of manganese as an enzyme activator in a number of enzyme systems like various hydrolases, kinases, decarboxylases, transferases, pyruvate kinase carboxylases, arginases, RNA polymerases etc. has been high lighted (Vallee and Coleman, 1964; Duggleby and Dennis, 1973; George and Cohn, 1973; Chu et al. 1974; Mizioroko et al. 1974; Villafanca and Colman, 1974). Rudra (1938) showed that manganese regulated the biosynthesis of ascorbic acid. Hester (1941) established a similar relationship. It was suggested that Mn^{++} may act as a cofactor in the synthesis of ascorbic acid. The oxidized form of manganese (Mn^{++} or Mn^{+++}) has been shown to oxidise ascorbic acid (Kenten and Mann, 1950). Even increase in crop yield as an effect of manganese treatment has been reported in various crops (Roberts, 1948; Drennan et al. 1961) indicating thereby the possibility of manganese association with general metabolism. Intermediate manganese content in two highly heterotic hybrids for grain yield, in comparison to their respective parents in the present study suggests a highly
balanced metabolism and regulation of hormones like IAA and GA as well as other active substances like AA. This ultimately results in efficient growth, development and yield.