DISCUSSION

At the outset it seems worthwhile to mention that the climatic and other environmental conditions prevailing in the Punjab, where the investigations reported herein were carried out, differ materially from those found in other important corn growing countries, notably the corn belt of the United States of America. In the Punjab maize is grown mainly in the sub montane districts, where owing to high intensity of cropping, the soils are almost exhausted. The row and plant spacings in vogue are comparatively closer in this State as compared to other countries. Furthermore, mechanised cultivation is nearly absent. The temperatures in the early period of growth are high and the monsoon rains are often uncertain and unevenly distributed. In the course of the present investigations, the weather conditions were widely different in the two years of study. The year 1950 was characterized by incessant rains during the period of growth and this interfered with the normal development and bearing of the plant. In the succeeding year, the season was normal and favourable to all round plant development. The vital role of the weather conditions in the cultivation of the maize crop was thus unmistakably demonstrated. The results obtained have, therefore, to be viewed in the above stated perspective. Though the experimental conditions were widely different from those of the United States of America and other countries, yet the findings of these investigations are in broad agreement with those reported elsewhere. The salient features
of the experimental results are discussed below.

**Application of nitrogen.**

The application of nitrogen in the form of ammonium sulphate proved to be very effective in enhancing the growth of the maize crop. Extension growth as measured by the height of the plant was significantly greater in the manured plots than in the control. This was expressed mainly through the increase in the internodal length. This is due to the fact that nitrogen enlarges the cells of plant tissues and plays a great role in the mobilization and utilization of carbohydrates in the building of the general plant body which ultimately finds expression in visible growth. The maximum increase in height with manuring was obtained with the first increment of nitrogen (50 lbs.), after which the effect of subsequent doses progressively fell off; so much so that the quantitative differences in height under 100 lbs. and 150 lbs. nitrogen per acre treatments were negligible in both the years. This strong curvature in the trend of response to doses of nitrogen at higher levels resulted in the significance of both linear and quadratic effects even at 1 percent level.

Similar increases in plant height were obtained by Innes (35), Luthra (51), Mann (52) and Sharma (75).

The number of nodes or leaves showed only a small increase with the first increment of 50 lbs. nitrogen per acre beyond which it remained nearly unchanged. Leaf expansion, on the other hand, was definitely well marked with the application of nitrogenous fertilizer. This was due to the expansion of cells by the addition of nitrogen. Similar results were
The application of nitrogen promoted all round plant development and induced early tasseling and silking as compared with control. Luthra (51) also obtained similar results.

The favourable effect of nitrogen on general plant growth was in turn reflected in better development of ears. The length of ears and the circumference of ears were significantly greater in the manured beds than in the control. Consequently the gross weight per ear as well as the yield of grain per ear improved with increase in the dose of nitrogen. The yield per ear is composed of the number of rows of grain, the number of grains per row and the size of grains. All these components were favourably influenced by the addition of nitrogen, but the effect was more marked on the number and the weight of grains. Crowther et al (30), Hinkle (23, 29), Hughes & Robinson (31), Hutcheson & Wolfe (34), Krantz (40) and Miller et al (56) also reported similar improvement in the development of the ear in maize. Along with ear size, their number per plant also increased with manuring, but the effect was comparatively small. Ordinarily maize developed only one ear per plant; but under doses of 100 lbs. and 150 lbs. N. per acre two ears were occasionally noticed. Hinkle (23) and Krantz (40) noticed that the number of ears increased with the application of nitrogen. Sharma (75), on the other hand, showed that there was very little increase in the number of ears per plant.

Nitrogen also was found to encourage the growth and development of prop roots as well as fibrous roots.
Results of a similar nature were reported by Shank (74) and Weaver (84). Although the root development improved with manuring, their consequent effect on lodging did not turn out to be regular. This again showed that lodging in maize did not entirely depend on the development of root system but was controlled by other soil and atmospheric conditions.

No relationship could be established between the incidence of maize borer (*chilo conelus*) and the nitrogen status of soil in either year. There was, however, a slight indication that the higher doses of nitrogen reduced the borer attack.

Lower nitrogen status was found to be one of the factors responsible for barrenness in maize plants. The highest number of barren plants was recorded in the control plots and their incidence decreased with increase in the dose of nitrogen. Croather et al (19), Mann (52), Miller et al (56) and Williams and Walton (86) also observed similar relationship between nitrogen supply and the extent of barrenness in maize.

Additional nitrogen supply raised the shelling percentage markedly in the first year but in the subsequent year this character was only slightly influenced by the various manural treatments. It appears that in the first year, owing to incessant rains and abnormal weather conditions, the development of grains in the control plots remained poor and was in turn reflected in low shelling percentage. When, however, nitrogen was supplied, it aided better development of grains and consequently improved shelling percentage. In the second year, weather conditions were normal and, therefore,
the development of grains and hearts was well balanced with
the result that there was practically no difference in the
shelling percentage under the various treatments.

The beneficial effect of the application of
nitrogen on the development of plants and ears culminated
in an enhanced yield of grain and stalks per acre. The
yield increased with an increase in the dose of the fertilizer
and the highest yield of both grains and stalks was obtained
from the highest dose of nitrogen. Similar increases in yield
were recorded by several workers mentioned under "Review of
Literature".

Spacing.

Two feet rows produced definitely taller plants
with longer internodes in the first year than one foot wide
rows. But in the second year, there was no such difference
under the two row spacings tried. The difference in the plant
behaviour in the first year may probably be due to abnormally
wet weather conditions. The variations in the spacings
between the plants in rows ranging from 2" to 15" had little
effect on the height and internodal length of the plants in
either year. Andie (23), Reelsen (30), Innes (35) and Sharma
(75) also noticed no distinct increases in plant height with
different rates of planting.

The number of leaves per plant was not influenced
by the different spacings tried between rows and plants owing
to the inelastic nature of this plant character. Similar
results were reported by Crowther et al (19) and Andie (23).
The leaf area was, however, found to be greater under wider
row and plant spacings on account of the availability of more space per plant.

The wider row spacing developed significantly thicker stems than the closer row spacing. This may be attributed to the availability of relatively greater amounts of nutrients. Hunt (33) also obtained identical results.

The tasseling period was not materially affected by the row or plant spacings. The silking period, on the other hand, was greatly advanced with wider row spacings than with closer ones. The plant to plant spacings exercised little effect on the development of silks. Kohnke & Miles (39) and Stringfield & Thatcher (73) reported that silking was delayed by thick planting.

The effect of wider spacing between rows was very conspicuous on the development of ears. Two feet wide rows produced longer, thicker and heavier ears than one foot rows. The plant spacings within the rows had a similar but less marked effect on ear development. This again is due to lower competition for soil nutrients among plants under the wider spacings. These observations are in agreement with the findings of Crowther et al (19), Engledow (22), Nealie (23), Hinkle (29), Innes (35), Kohnke & Miles (39), Latta (45), Muhr & Post (62) and Olson (65), and several other workers.

While the number of seed rows on the ear was not affected by the rate of planting, the number of grains in each row and the size of grains were found to be greater in wider spacings than in closer spacings. Wider spacings, whether between rows or plants, were invariably conducive to better
bearing in as much as they yielded a larger number of ears
per plant.

Although the development of prop roots and
fibrous roots was better under wider than under closer spacings
on account of better development of individual plants, yet
these spacing treatments showed no visible effect on lodging
in maize. Bryan et al (14), Kohnke & Miles (39), Krantz &
Chandler (41), Olson (65), Roberts & Kinney (69) and
Stringfield & Thatcher (78) noticed that lodging in corn
increased with increasing plant population.

The wider row spacings showed greater incidence
of borer attack than the closer row spacings. This can be
explained on the basis of relative plant populations and the
number of invading insect pests. Smaller plant population under
wider spacing on this hypothesis should show a higher
percentage of borer attack.

Thicker plantings were accompanied by an
increased rate of barrenness, presumably owing to the fact
that, under thicker plantings, on account of keen competition
for food factors some of the plants failed to bear ears. These
findings are in accord with those of Crovther et al (19),
Haber (27), Hunt (33), Klessbach et al (29), Muhr & Rost
(62), Olson (65), Stringfield & Thatcher (78), Wallace &
Bressman (82) and Williams & Walton (36).

The shelling percentage was not appreciably
affected by row or plant spacings, showing thereby that the
development of grains and hearts was well coordinated under
these spacing treatments. Bryan et al (14) also did not notice
any significant difference in the shelling percentages of
different plant spacings.

Even though the individual plant and ear development were better under wider spacings, this beneficial effect was not enough to compensate for the small plant population per unit area. This is evident from the fact that in both the years of study, the yields of grain and stalks per acre were decidedly more in the closer row spacing than in the wider spacing. One foot wide rows significantly outyielded the two feet rows both in grain and in stalks. Closer spacings between the rows showed a similar but less marked favourable effect. Similar results have been demonstrated by several workers. Since the cultivator is ultimately interested in yield per unit area rather than the yield of individual plants, it seems logical to conclude that under the Punjab conditions, one foot spacing either way is likely to give the highest return per acre.

**Interactions of spacing and nitrogen.**

Under low levels of nitrogen, the wider rows were found to be conducive to better height, while at higher levels of nitrogen the height of plants was the same irrespective of the distance between rows. Similarly wider plantings within rows increased the height only under conditions of nitrogen deficiency (N0), whereas with the application of nitrogen, plant to plant spacings ceased to make any difference. Likewise, the area of leaves showed considerable improvement by increasing the available space per plant within rows, but it was so only up to a certain limit, beyond which there again set in a decline in leaf
expansion.

As for internodal length, both the application of nitrogen and the provision of greater space per plant resulted in the formation of larger internodes, but the effects being additive the combinations of these two factors at intermediate levels did not show any marked difference, while a combination of the highest levels (N3 S3) showed a regression in internodal development.

There was also an indication that wider planting within rows encouraged the formation of thicker stems, more especially in the absence of nitrogen; but when nitrogen was added, the effects of wider plant spacing became less marked.

The significance of RxS interaction on the circumference of the ear implied that one foot rows were too close and when plants were sown progressively wider apart under this type of spacing, the result was better development of the individual ears on account of compensatory growth; but in two feet wide rows no such advantage accrued from wider plantings within the row. The effect of row spacings on the number of grains per row was largely influenced by the nitrogen level. Wider spacing was effective in increasing the number of grains per row only under control and the first low dose of nitrogen. In the presence of higher doses of nitrogen, it was immaterial whether the rows were sown close or wide.

In the matter of 1000-grain weight, wide spacing appeared to be conducive to the formation of heavier grains on account of the availability of more space per plant but
the magnitude of its beneficial effect was not identical at all levels of nitrogen. In the control plots the difference in grain development in favour of wide spacing was small because wide spacing alone was not enough to make up for the general deficiency of nitrogen present in the field. When additional nitrogen was applied in the form of artificial fertilizer, the effect of wide spacing on grain development became more pronounced.

On stalk yield, nitrogen showed differential effects at the varying levels of the spacing factors in 1950. Whether spacing was reduced by closer rows or by closer planting within rows, it invariably resulted in increased yield of stalks, but the increase under closer spacing was particularly more marked when fertilizer was applied than under control. This is due to the more efficient removal of nitrogen from the soil by the closely spaced crop. Similar interactions of nitrogen and spacing were observed on the yield of grain. The application of nitrogen increased the yield, but to derive the maximum benefit from this investment, closer spacing both in rows and between plants was an essential factor. It is noteworthy that, in general, the higher the dose of nitrogen the greater the differential effect of closer spacing. Crowther et al (19), Hinkle (29), Seem and Huber (73), and Sharma (75) reported a similar relationship between nitrogen and spacing in the matter of grain yield.

The closer row spacing tended to lower the shelling percentage but such spacing effects were neutralized by the application of nitrogen.
Protein content of grains.

The protein content of maize grain increased with the application of nitrogen as well as under wider spacings. Thus the added nitrogen not only enhanced general plant growth but also increased the concentration of this element in the plant body and improved its nutritional value. This is in accord with the results obtained by Crowther et al (19), Krantz (40), Krantz and Chandler (41), Luthra (51) and Nelson (63).

Residual effect of treatments.

The residual effect of spacing and manorial treatments given to maize was studied on the succeeding wheat crop. Wider row and plant spacings showed a slightly higher residual effect than closer spacings. Identical results were reported by Brandon (12) and Crowther et al (19). The residual effect of the various doses of fertilizer was well marked and the highest yields of grain and straw of wheat were obtained from the application of 150 lbs. nitrogen per acre. Similar results were reported by Crowther et al (19), Dumenil (20), Luthra (51) and Sharma (75), indicating that the application of high doses of nitrogen not only directly benefit the crop to which these are applied but the succeeding crop as well.

Economics of manuring.

The economics of manuring with ammonium sulphate applied directly to maize crop was worked out and it was found that the highest net profit of Rupees 45.85 was recorded with the application of 50 lbs. nitrogen per acre. The net profit per acre decreased with the increase in the dose of the fertilizer due to its high cost. But when profit and loss
account was reworked taking into account both maize and wheat crops, then the highest net profit of Rupees 151.33 was obtained from the highest dose of the fertilizer, i.e., 150 lbs. nitrogen per acre. This is due to the fact that the residual effect was the highest from the highest dose of the fertilizer and this additional gain covered the cost of the added fertilizer.

**Correlation studies.**

The maize plant exhibited a harmonious development of all tissues under the influence of variations whether of climatic or edaphic origin. All the characters under study were found to be positively related with yield, varying of course in magnitude according to the force of their determining effect on grain yield. The stalk characters such as yield of stalks, height and the girth of the stem possessed stronger association with yield than rest of the characters.

The number of leaves being a less variable character of the maize plant, did not show any relationship with grain yield; whereas its component, viz., the size of leaves showed varying effects in the two seasons. During the first year a general check on the growth of the crop owing to incessant rain was accompanied by a natural limitation of leaf expansion and thus the leaf area and yield showed a weak correlation in contrast to the second year when the correlation figure was very high and significant even at 1 percent level. This was due to favourable conditions for the rank growth of the crop during the second year.

Most of the ear characters also showed medium
but positive correlations with yield. Of these ear weight and 1000-grain weight appeared more significant, followed by ear circumference and the number of grains per row. The characters of the number of grain rows per ear and the number of ears per plant being inelastic could not have a concomitant variation with grain yield.

Other development characters also exhibited mutual relationship, and, of these, the yield of stalks showed a strong and positive correlation with the height of plants and the weight of ears during both the years. The girth of the stem and the number of ears per plant did not show any marked relationship, their correlations were found to be positive but non-significant. The most probable cause for this incongruency is the inelastic nature of the number of ears per plant.

The girth of the stem and weight of 1000 grains showed a weak correlation in the first year but a significant relationship in the second year. This was on account of shortening of extension growth due to poor aeration in the root zone under incessant rains and consequent thickening of the stem. The effect of this unfavourable factor was also reflected in grain development and the net result was that in 1950, greater girth was not accompanied by a similar increase in the 1000-grain weight. The length of the ear showed strong and positive relationship with yield in the first year, but weak correlation in the second year. The season in general was very favourable for extension growth during the second year, and the variations in the ultimate
length of the ears were less marked and its effect on grain yield less significant.

**Optimum sowing time.**

The date of sowing was another important factor under study. It was found that, amongst the four dates of sowing tried at 10 day intervals, the second sowing, done on July 15, produced the tallest plants, followed closely by July 5th and July 25th sowings. The crop sown on 4th August was the smallest owing to the shorter period of growth. The attack of borer (*Chilo zonellus*) in the first year was found to be the greatest in the first sowing and decreased with each delay in sowing. During the second year also, a similar trend of borer attack with varying sowing dates was observed; but the differences between the first and the second sowings were statistically non-significant. The cause of greater damage by borer to the early sown crop appears to be the synchronisation of the best breeding season of this insect pest with the appearance of seedlings of the early sowing.

The percentage of barren plants was decidedly lower in the first sowing than in the remaining three sowings during both the years. The number of barren plants increased with the development of the sowing time and the last sowing had significantly more barren plants than the other sowings. This may be associated with the limitations imposed on the period of growth of this quick growing short seasoned crop. This is in accord with the results obtained by Williams & Welton (36).
The development of grains was noticed to be better in the second and the first sowings in both the years. The fourth sowing showed the poorest development of grains as was indicated by the lowest shelling percentage in this case. Improper development of grains under the last sowing is due to the lack of sufficient carbohydrates reserve which could be mobilized for ear development.

The yields of grain and stalks per acre were found to be the highest in the second sowing, i.e., the crop sown on the 15th July. The first and the third sowings occupied the intermediate position in this respect. The yields were poorest in the fourth sowing done on 4th August.

Efficiency of organic and inorganic manures.

Farmyard manure, groundnut cake, ammonium sulphate, ammonium phosphate, each at the rate of 100 lbs. nitrogen per acre and superphosphate at 125 lbs. phosphoric acid per acre were tried against control. The growth in height was the maximum in ammonium sulphate and ammonium phosphate plots, while groundnut cake came next in order. There was practically no difference in the heights of plants under farmyard manure, superphosphate and control treatments. Vigorous growth resulting from ammonium sulphate and ammonium phosphate also enabled the plants to withstand the attack of the maize borer a little better. Barren plants were also fewer under these two treatments. The application of those inorganic nitrogenous fertilizers resulted in a higher outturn of grain and stalks per acre than the application of the other slow-acting organic manures. Out
of the organic manures, groundnut cake was decidedly superior to the rest. Farmyard manure and superphosphate showed no difference over control.

It can be concluded from these results that nitrogen is the chief limiting factor in the cultivation of maize crop. It should be supplied through quick acting inorganic fertilizers like ammonium sulphate and ammonium phosphate. The organic manures, like groundnut cake and farmyard manure, are slow to act and have not proved useful for a quick growing crop like maize. There is practically no response to the application of superphosphate.