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THE "TROPICAL AGRICULTURIST" IS REGISTERED AS A NEWSPAPER IN CEYLON

The effect of time of application of nutrients on nutrient recovery and growth of the potato

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(Received April, 1970.)

INTRODUCTION

The increase in tuber yield with late or split applied nitrogen compared with nitrogen applied at the time of planting was suggested to be due to the greater efficiency of its recovery (Gunasena and Harris, 1968, 1969). The lower efficiency in the recovery of early applied nitrogen was largely attributed to leaching losses owing to the heavy rainfall experienced in early spring. Leaching of nitrogen could take place at any time of the year, but the period of greatest danger appear to be the early spring under British conditions. At this time the temperature is low and the soil is often saturated, therefore even a moderate rainfall could cause a considerable loss of early applied nutrients. The absence of a crop cover for a period of 4-6 weeks after fertilizer application and planting could also favour their movement into the deeper layers of soil (Woldendorf, Dilz and Kolenbrander, 1965). Under these conditions not only will the volume of drainage be greater, but also the amount of soil nutrients in the soil solution will be higher This seems to be a satisfactory explanation for the lower efficiency of recovery of nitrogen applied at the time of planting for crops planted in Spring.

With main crop potatoes normally planted and fertilizer applied when evaporation is increasing the risk of losing early applied nutrients may be reduced. An experiment was designed to test this possibility for nitrogen and potassium using the main crop variety Pentland Dell. An attempt was also made to restrict the excessive stem growth associated with late top dressings of nitrogen (Gunasena, 1968, unpublished data) by spraying a growth regulating chemical, (2-Chloroethyl Trimethyl Ammonium Chloride, CCC) when the leaf area index was near the optimum for tuber production (Radley, 1963).

EXPERIMENTAL

Location and Soils.—The experiment was conducted at the Reading University Farm Sonning-on-Thames, in 1968. The soil was a freely drained sandy loam, the surface soil containing 80 per cent coarse and fine sand in equal proportions. The soil type designated Sonning Series has been described by Kay (1936).

Treatments.—The nitrogen and potassium treatments consisted of a control and three times of application, *i.e.*, at the time of planting (early), at the time of tuber initiation (late), both at planting and tuber initiation (Split). Nitrogen was applied as ammonium nitrate at the rate of 1.75 cwt. N per acre. The split application received 0.75 cwt. N per acre at the time of planting and the remainder at tuber initiation. Potassium as muriate of potash was applied at the rate of 2.25 cwt. K_2O per acre. When split 1.0 cwt. K2O per acre was applied at the time of planting and the remainder at the time of tuber initiation. The nitrogen and potassium treatments received potassium and nitrogen respectively, at the time of planting. All treatments received a dressing of phosphorous at the rate of 1.25 cwt. P_2O_5 per acre at the time of planting.

Early dressings of fertilizer were rotavated in on 17th April, while late fertilizers were top dressed on 29th May. CCC was sprayed to the foliage at a concentration of 3.5 g./litre (3.45 lb./acre) on 30th June when the leaf area index was approximately 3. The seven fertilizer treatments were combined with and without CCC.

Grade " A " seed was planted on 18/19th April.

All treatments were arranged in randomized blocks, replicated three times. Each treatment was sub-divided into nine subplots for sequential sampling at 2 week intervals. Each main plot contained four rows of potatoes spaced 24 in. apart, with tubers spaced 14 in. within rows. Each sub plot contained four plants in each row. The outer rows in each sub plot were treated as discard rows and only 4 plants per plot were sampled at each harvest.

The sampling procedure adopted at each harvest was as follows: The foliage of one plant cut at ground level was transferred to a polythene bag for the subsequent estimation of leaf area. The remaining 3 plants were treated similarly and foliage put in a separate polythene bag. Tubers were then lifted by a hand fork and bagged. All samples were taken into a laboratory where separations into leaves, stems and tubers were carried out as soon as possible. The foliage of the plant required for the estimation of the leaf area was dealt with first; the separated leaves of this plant were weighed to the nearest gram, rebagged and stored in a refrigerator until they could be dealt with. After separating the components of yield they were weighed and sub-samples were removed for the estimation of dry matter content. Very few tubers were present at the first harvest and their weights were not recorded.

The leaf area was estimated by the disk method described by Watson and Watson (1953). The cross sectional area of the disk was 1.432 cm^2, and 75—100 disks were taken for each sub sample.

Climate.—The climatic data is given Table 1. The early part of the growing season was very wet and the rainfall during the first month after planting exceeded 3.5 inches, and the accumulated drainage over the same period (calculated after the method of Stanhill, 1958) was more than 1.6 inches. The period after August was unfavourable for growth due to the occurence of Blight (*Phytophthora infestans*) which caused premature leaf senescence.

RESULTS

Tuber fresh weight data.—As reported earlier (1968, 1969) the time of tuber initiation was not affected by the time of application of nutrients, therefore at the 2nd harvest both the control and the late nitrogen treatments recorded lower tuber yields compared with early or split nitrogen treatments, (Table 2). This suggests that factors other than nitrogen may be influencing tuber initiation. Late nitrogen was inferior to that applied early during the early period of growth and the decline in yield at the 3rd harvest was 81% of that with early nitrogen. The subsequent growth with this treatment was rapid and at the final harvest yield was increased by 12% compared with early nitrogen. Split nitrogen had a non significant positive effect at the 2nd and 3rd harvests and also at the final harvest compared with early nitrogen. Potassium treatments and CCC had no significant effect on tuber yield at any harvest.

Significant interactions between treatments were recorded at the 4th and 6th harvests. On both occasions split nitrogen increased the yield of tubers in the presence of CCC, but not in its absence compared with all other treatments. This trend was not maintained in the subsequent harvests probably due to the occurence of blight.

Mean tuber bulking rates were calculated from the 4th to the 14th week using a linear regression equation, $Y = a+b.\ t$, where Y = yield of tubers (tons/acre), a =constant, b = rate of tuber bulking in tons/acre week, and t = time measured in weeks (Table 3). The bulking rates were linear ($r = 0.99$). The tuber yields closely correlated with bulking rates except in the late nitrogen treatment where the rate and duration of tuber bulking was involved.

Dry-matter accumulation and distribution.—The pattern of dry-matter accumulation was similar to those described earlier (1968, 1969), and progressed steadily through the growing season until growth was interrupted by sporadic attacks of leaf blight in early August.

There were no significant interactions between treatments. Nitrogen had a marked effect on dry-matter accumulation (Fig. 1 a). Early nitrogen increased total dry-matter yield from 3rd to 6th harvest. Late nitrogen depressed dry-matter accumulation initially. The growth continued with both late and split nitrogen treatments after the 6th harvest and these two treatments were significantly better than early nitrogen at the 7th harvest. There were no significant differences in tuber dry-matter yield with split and early nitrogen treatments untill the 6th harvest, thereafter split nitrogen increased tuber yield compared with early nitrogen (Fig. 1 b). Late nitrogen depressed tuber dry-matter yield up to the 7th harvest compared with early nitrogen ; in the later harvests it had an effect similar to that of split nitrogen.

Potassium treatments had no significant effect on yield components throughout the entire growing period. CCC had no effect on leaf and tuber dry-matter yields. CCC had the greatest effect on stem dry-matter yield (Table 4.) and reduced it significantly at the 5th, 6th and 7th harvests. As a result CCC reduced total dry-matter yield.

The pattern of distribution of dry-matter was similar to those reported earlier, (1968, 1969). In essence, both late and split nitrogen treatments increased the proportion of leaf and stem in total dry-matter, the consequence being a reduction in the proportion of tuber in total dry-matter. Potassium treatments had less effect ; while CCC, adversely affected the proportion of stem in total dry-matter.

Accumulation of Nitrogen and Potassium in the crop

(*a*) *Nitrogen.*—There was a good response to applied nitrogen (Fig. 2 a). Early nitrogen had a greater effect during the early period of growth. Split and late nitrogen treatments increased the uptake of nitrogen from the 4th and 5th harvests respectively, compared with early applied nitrogen. The rate of uptake of nitrogen during the 42 day period between 3rd to 6th harvest was greater with late and split nitrogen (3.4 lb. N/acre/day), compared with early applied nitrogen (2.6 lb. N/acre/day) over the same period. The highest accumulation of nitrogen in the leaf occured with late nitrogen at the 5th harvest when 103 lb. N/acre was present in the leaves. This was 29% more compared with early and split nitrogen. Potassium treatments and CCC had no significant effect on nitrogen uptake.

(*b*) *Potassium.*—The effect of nitrogen treatments on potassium uptake was similar to the effect of these treatments on nitrogen uptake, (Fig. 2 a). Both late and split nitrogen increased the uptake of potassium after the 4th harvest, the highest uptake was recorded for the split nitrogen treatment at the 7th harvest when 412 lb K/acre was present in the crop (Fig. 2 b). Potassium treatments had less effect on potassium uptake. In the absence of potassium crop recovered 283 lb. K/acre and the lack of response to applied potassium may have been due to the high soil potassium status. Late and split potassium tended to be more effective towards the latter part of the growing period, but this effect was not fully developed due to the onset of blight.

Distribution of the nutrients in the crop closely followed the pattern of dry-matter distribution.

Growth Attributes

(*a*) *Apparent net assimilation rate* (*"NAR"*). The rate of increase of dry-matter per unit leaf area was calculated according to Gregory (1926),

Where W_2 and W_1 are dry weights, and L_2 and L_1 are leaf areas at times t_2 and t_1 respectively.

$$\frac{(W_2 - W_1)(\mathrm{Log_e}\, L_2 - \mathrm{Log_e}\, L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

Owing to the difficulty encountered in measuring the rate of decay of the parent tuber the contribution made by the latter towards dry-matter production of the crop has been excluded from this calculation, hence the term Apparent net assimilation rate ("NAR".)

"NAR" values were highly variable and tended to decline with time (Fig. 3). Significant differences between nitrogen treatments were recorded on two occasions ; at the 2nd and 3rd harvest period the control treatment was significantly better than split and early nitrogen treatments, while at the 3rd and 4th harvest period the control treatment was superior to all other nitrogen treatments. At both these harvest periods there was a significant negative correlation between leaf area (L) and "NAR" (Table 5) suggesting that the decrease in "NAR" was associated with an increase in leaf area resulting from the mutual shading of leaves (Watson, 1958).

Although potassium is reported to play a prominent role in photosynthesis (Cooper, Blazer and Brown, 1967 ; Bershtein and Okanenko, 1966), potassium treatments had no significant effect on "NAR".

(b) *Specific leaf area.*—*(A/LW)*. A close relationship between leaf thickness measured by micrometer and leaf dry weight per unit area has been reported by Friend (1965). This ratio reffered to as the specific leaf area could be used as an indirect measure of leaf thickness where a high ratio would correspond to a thinner leaf. Both late and split nitrogen increased A/LW towards the end of the growing season compared with early nitrogen (Fig 4A), potassium had less effect on A/LW. CCC reduced A/LW.

(c) *Leaf weight ratio*—*(LW/W)*. A measure of the distribution of dry-matter between leaves and the rest of the plant is provided by the leaf dry weight (LW) per total dry weight (W) of the plant, [Fig. 4B]. Early nitrogen increased LW/W up to the 2nd harvest. After the third harvest both late and split nitrogen increased the proportion of dry-matter utilized for leaf production. Potassium treatments and CCC had less effect on this ratio.

(d) *Leaf area ratio*—*(LAR)*. LAR is the product of A/LW (differences in leaf thickness) and LW/W (differential distribution of photosynthetic products between leaf growth and other plant growth). Therefore any variation in LAR could be attributed to the variation in either of the above ratios [Fig. 4c]. Due to an increase in LW/W early nitrogen increased LAR up to 2-3 harvest period. In the later harvest periods late and split nitrogen increased LAR compared with early nitrogen. This was mainly due to the greater partitioning of dry-matter for leaf production as shown by the high LW/W. CCC depressed LAR mainly due to a lower A/LW, (thicker leaves).

(e) *Leaf area index*—(*L*). The peak L values were recorded towards the latter part of July (Fig. 5). Early nitrogen increased L up to the 3rd harvest. Late nitrogen depressed L and by the 2nd harvest L had declined to 67% of that with early and split nitrogen. During the later stages of growth both late and split nitrogen increased L compared with early nitrogen. Late and split application of potassium increased L towards the later stages of growth compared with potassium applied early. CCC reduced L.

Leaf area duration (D) was increased with both late and split applications of nitrogen (Table 6). Early potassium increased D by 15%, split potassium increased D slightly while late potassium decreased D compared with early potassium.

DISCUSSION

In the period immediately after planting and fertilizer application the crop was exposed to very wet weather conditions. As shown earlier (Table 1. Climatic data) the rainfall during the first month after planting exceeded 3.5 inches and the estimated drainage over the same period was more than 1.6 inches. Inspite of the wet weather there was good response to early applied nitrogen at least during the early stages of growth. This was evident from the dry-matter yields (Fig. 1) and the nutrient uptake data (Fig. 2). Two reasons could account for this response, firstly the time from planting to emergence was shorter in the main crop, hence the crop would have absorbed a grater proportion of the soluble nutrients, therefore the soluble nitrogen in the soil solution was lower, secondly increasing evapotranspiration may have reduced the amount of drainage. Although the initial response was high, the recovery of early applied nutrients was less compared to those applied late (Table 7). The nutrient recovery values were very high. This may have been due to the increased root growth caused by applied fertilizer (Broadbent, 1965) or the applied fertilizer may have increased the release of soil nitrogen, (Legg and Allison, 1960). The efficiency of recovery of nitrogen applied late or split was over 100% compared with

82% recovered with early nitrogen. Of the potassium treatments only split potassium improved the recovery of applied potassium. A striking feature in the recovery data was the improvement in the recovery of early applied potassium when nitrogen was applied late or split.

From the foregoing evidence the greater recovery of late and split applied nitrogen cannot be entirely attributed to the losses by leaching of early applied nitrogen. Applied nitrogen could get lost in other ways. Some nitrogen may be lost as ammonia gas, but this process is reported to be of little practical importance except on calcarreous soils (Garner, 1959). Recent investigations have shown the possibility of serious losses of nitrogen by denitrification (Allison, 1965).

As shown in Fig. 6 the accumulation of nitrogen is greater than the accumulation of dry-matter. This trend is similar for different potato varieties and the pattern is identical in all years (Gunasena, 1968 unpublished data). It is also apparent from the figure that the accumulation of nitrogen is greater in relation to the accumulation of dry-matter with early applied nitrogen compared with late or split applied nitrogen. Viets Jr. (1965) reported similarly using the data of Carpenter (1963). According to Viets Jr. the accumulation of nitrogen relative to the accumulation of dry-matter is of great significance, firstly as nitrogen stored in the plant is protected from leaching or denitrification losses, and secondly as it could be recirculated to the developing organs during the later stages of growth. The recirculation of mineral nutrients is unlikely in the potato, as once the tubers are initiated they form dominent "Sinks" for both carbohydrates and mineral nutrients. As growth proceeds the supply of mineral nutrients in the external solution is depleted and the rate of uptake is reduced. Therefore a stage will be reached when the uptake of nutrients is inadequate to sustain the growth of the whole plant, then the nutrients required for the growth of the tuber appear to be supplied by transfer from the haulm (Milthorope, 1963, Moorby, 1968). In this experiment when nitrogen was applied early a greater proportion of it was found to be accumulated in the tuber compared with that applied when the crop was growing. Late growth has to be maintained either by nitrogen stored within the plant or bv uptake of inorganic nitrogen from the soil. From evidence presented above, even at high rates, nitrogen applied at the time of planting will be inadequate to maintain late growth, for if it is not taken up by the crop it could get lost by leaching or denitrification, and if absorbed by the plant it gets locked up in non-photosynthetic organs of the plant and may not be available for the subsequent growth of leaves. It is therefore evident from the results that late top dressings could be useful to prolong the period of growth. A larger tuber yield could be obtained from a large leaf surface only when the growing period is sufficiently prolonged. The nutrients applied at a time when crop is growing is therefore better utilized than when equal quanties are applied at the time of planting.

As reported earlier (1968, 1969) the variation in leaf area was found to be the major factor causing variations in yield. As shown in table 8 there was a good relationship between total and tuber dry-matter yields and D, which accounted for 78% of the variation in yield. In this experiment the L values were higher than the optimum L of 3 suggested by Radley (1963). However there was no improvement in the relationship between yields and D when L above 3 were recorded as equal to D^3. Therefore there was no indication of an optimum L and this may be due to the closer spacing adopted which may have changed the morphological attributes of the crop. (24×14 inches compared with 28×15.4 inches).

The variation in D could be satisfactorily explained in terms of the maximum uptake of nitrogen (Nm) in the leaves. The relationships between D and maximum uptake of nitrogen in leaves was significant and the quadratic regression accounted for 91% of the variation in D. This relationship was expressed by the equation, $D = 8.69907 + 1.6949\ Nm - 0.0061\ Nm^2$. If the leaf growth was not curtailed by blight this relationship would probably have been linear. Harris (1960) reported similarly when leaf growth was curtailed in the variety King Edward by an attack of early blight. In view of the relationships between D and yield, and D and maximum uptake of nitrogen in the leaves it is not surprising that late and split applications of nitrogen which improved the recovery of applied nitrogen increased the tuber dry-matter yield.

SUMMARY

The effect of time of application of nitrogen and potasssium on nutrient recovery and growth of the main crop potato variety, Pentland Dell, was studied by the technique of Growth Analysis. The late and split applications of nitrogen improved the efficiency of

recovery of applied nitrogen compared with nitrogen applied at the time of planting. The late and split applications of nitrogen also improved the recovery of early applied potassium. Because of these factors late and split applications of nitrogen increased tuber yield.

There was a good relationship between total and tuber dry-matter yields and leaf area duration (D), D accounting for 78 per cent of the variation in both total and tuber dry-matter yields. The maximum accumulation of nitrogen in the leaves was related to D, and accounted for 91 per cent. of the variation in D. The increase in yield of tubers with late or split nitrogen treatments is therefore a reflextion of the nitrogen recovery.

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TABLE I. CLIMATIC DATA 1968

Period	Rainfall inches	Soil Moisture deficit, inches	Accumulated drainage, inches	Temperature F° Max.	Min.	Soil 4
April 18—1 May	1.57	0.15	0.72	61.9	40.6	49.6
„ 2—15 „	1.89	0.04	0.93	57.1	40.9	49.4
„ 16—29 „	0.98	0.23	0.25	58.8	42.1	52.2
„ 30—12 June	1.14	0.48	—	68.8	47.8	59.5
„ 13—26 „	1.09	2.26	—	69.8	51.8	61.0
„ 27—10 July	2.06	2.65	—	71.5	48.9	61.3
„ 11—24 „	1.27	1.82	—	67.5	52.3	60.5
„ 25—7 August	1.94	1.95	—	65.8	51.9	60.4
„ 8—21 „	1.82	0.66	—	66.0	50.6	59.9
„ 22—4 September	0.77	0.92	—	69.7	52.1	59.1
„ 5—11 „	0.76	0.24	—	68.8	50.8	59.7

TABLE II

The main effect of treatments on tuber fresh weight, tons/acre

Harvest Number	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
Treatments								
No. N	1.4	5.0	8.7	13.5	14.7	16.8	15.6	17.1
Late N	1.5	6.2	9.6	16.9	21.4	27.9	27.5	33.3
Split N	1.9	6.7	11.7	16.9	23.8	30.2	29.9	33.0
No. K	1.8	5.9	10.7	16.4	22.3	24.4	24.8	27.7
Late K	1.5	6.0	10.8	16.5	22.5	26.5	24.8	31.3
Split K	1.9	5.7	10.6	18.6	24.0	26.9	28.2	30.2
Early N/K	1.6	6.2	11.9	18.5	24.1	24.6	25.5	29.7
LSD (P=0.05)	N.S.	1.1	1.8	2.8	3.0	3.2	4.1	3.6
With CCC	—	—	10.3	16.6	21.8	24.5	25.4	28.4
Without CCC	—	—	10.8	16.9	21.8	26.1	25.0	29.3
LSD (P=0.05)	—	—	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C. V. (%)	36.9	16.3	14.6	14.0	11.7	10.7	13.9	10.4

TABLE III

The main effect of treatments on mean tuber bulking rate, tons/acre/week

	Tons/acre/week	*r.*
No. N	1.58	0.98
Late N	2.64	0.99
Split N	2.83	0.99
No. K	2.40	0.99
Late K	2.57	0.99
Split K	2.68	0.99
Early N/K	2.50	0.98
With CCC	2.40	0.99
Without CCC	2.51	0.99

TABLE IV

The effect of CCC on stem dry matter yield lb./acre

Harvest Number / *Treatments*	S_4	S_5	S_6	S_7
With CCC	11.5	12.41	10.94	9.69
Without CCC	12.5	14.75	13.65	12.59
LSD (P=0.05)	N.S.	1.37	1.46	2.05
C. V. (%)	12.8	12.0	23.2	28.8

TABLE V

The relationship between Leaf area index and Apparent net assimilation rate ; g/dm²/week

Harvest Interval		R^2
2—3	"NAR"=1.02281–0.12136 L	71%
3—4	"NAR"=0.87933–0.10938 L	91%

TABLE VI

The main effect of treatments on leaf area duration

Treatments	*D–weeks*
No. N	19.34
Late N	47.20
Split N	48.03
No. K	39.79
Late K	44.94
Split K	46.52
Early N/K	45.69
With CCC	40.65
Without CCC	42.64

TABLE VII

The percentage of applied nitrogen and potassium recovered in the crop

Treatments	*N*	*K*
Late N	109	60
Split N	106	75
Late K	84	46
Split K	92	62
Early N/K	82	48

TABLE VIII

The relationship between total and tuber dry-matter yields and leaf area duration, D.

		R^2
Total dry matter /D	Y=46.3821+2.3483 D	78.4
Tuber dry matter/D	Y=49.0735+1.7678 D	78.1
Total dry matter /D³	Y= –13.7226+5.3995 D³	75.8
Tuber dry matter/D³	Y=4.8582 +4.0295 D³	74:3

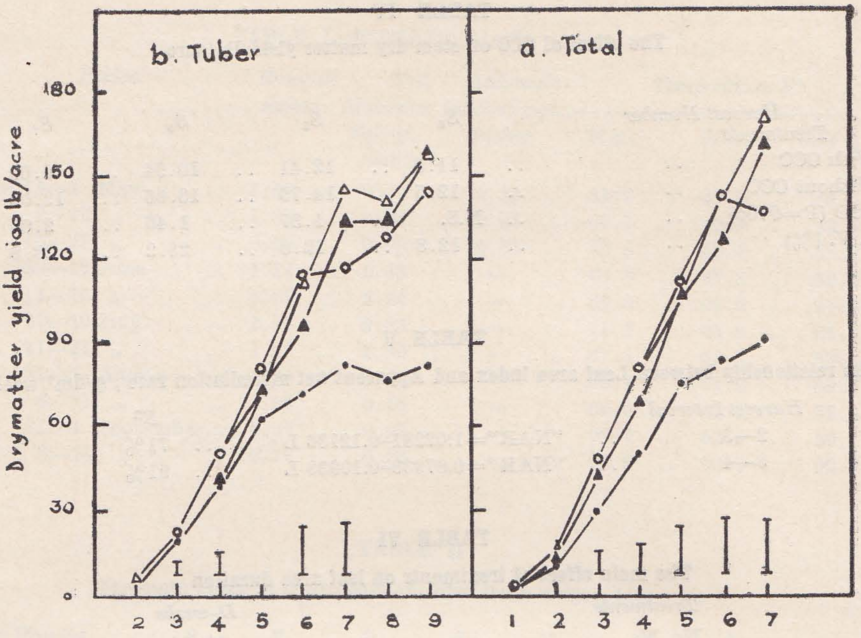

Fig. 1.—The main effect of nitrogen treatments on total and tuber dry matter accumulation.

[In all figures vertical straight lines refer to LSD's calculated at a probability level of 0.05.]

Legend

. . . . . .●. . . . . no N

. . . . . .▲. . . . . Late N

. . . . . .△. . . . . Split N

. . . . . .○. . . . . early N

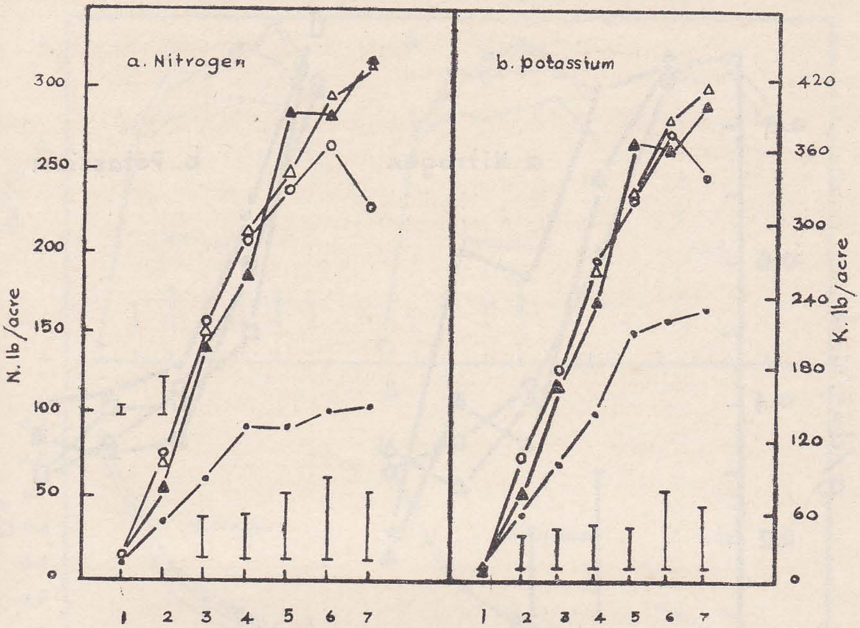

Fig. 2.—The main effect of nitrogen treatments on total nitrogen and total Potassium accumulation.

Legend

. . . . . .●. . . . . no N
. . . . .▲. . . . . Late N
. . . . .△. . . . . split N
. . . .○. . . . . early N

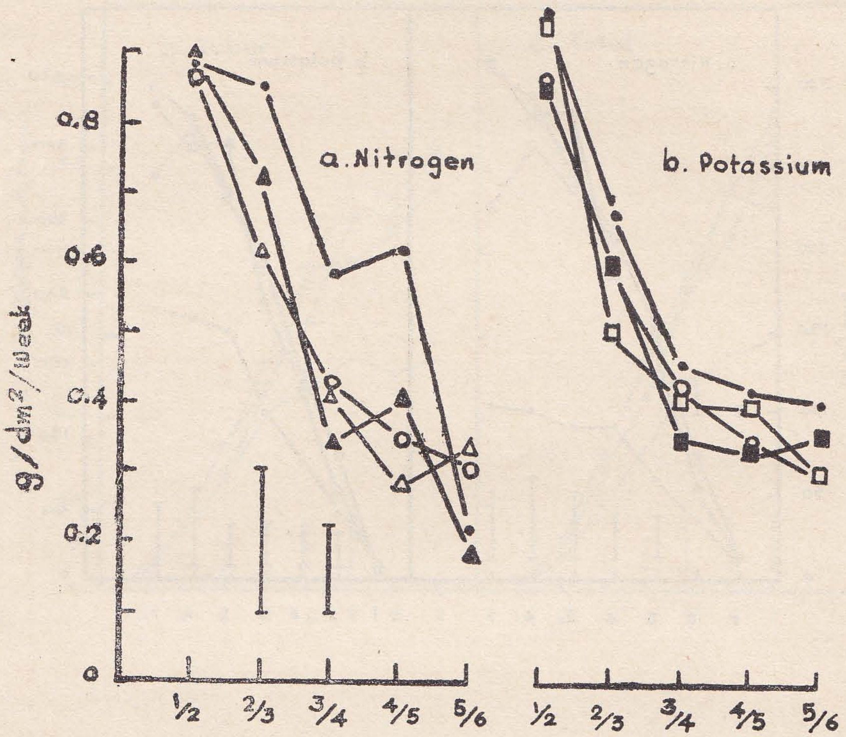

Fig. 3.—The main effect of nitrogen and potassium treatments on Apparent net assimilation rate.

Legend

●	no	N
▲	Late	N
△	split	N
○	early	N
●	no	K
■	late	K
□	split	K
○	early	K

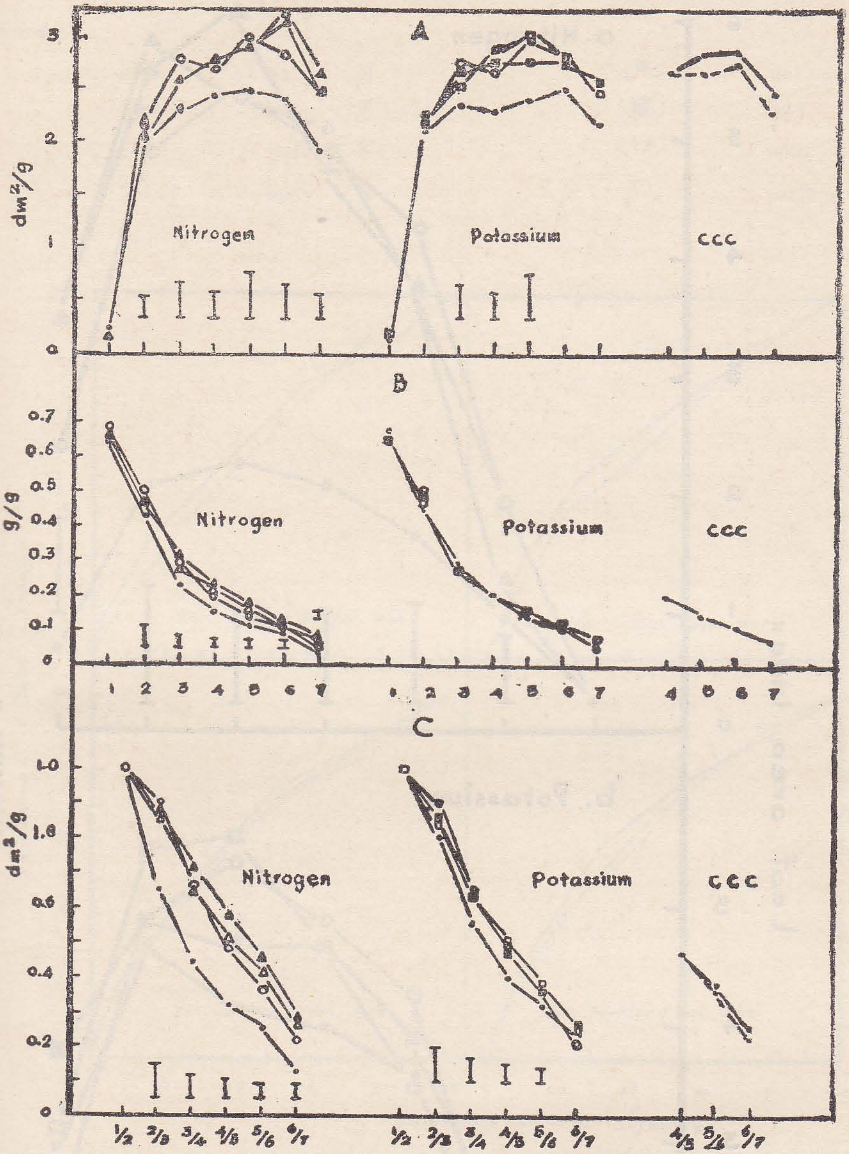

Fig. 4.—The main effect of nitrogen, potassium and CCC on Specific leaf area, A, Lea f weight ratio, B, and Leaf area ration, C.

Legend

●	no	N	■	late	K
▲	late	N	□	split	K
△	split	N	○	early	K
○	early	N	● — — ●	with CCC	
●	no	K	● —— ●	without CCC	

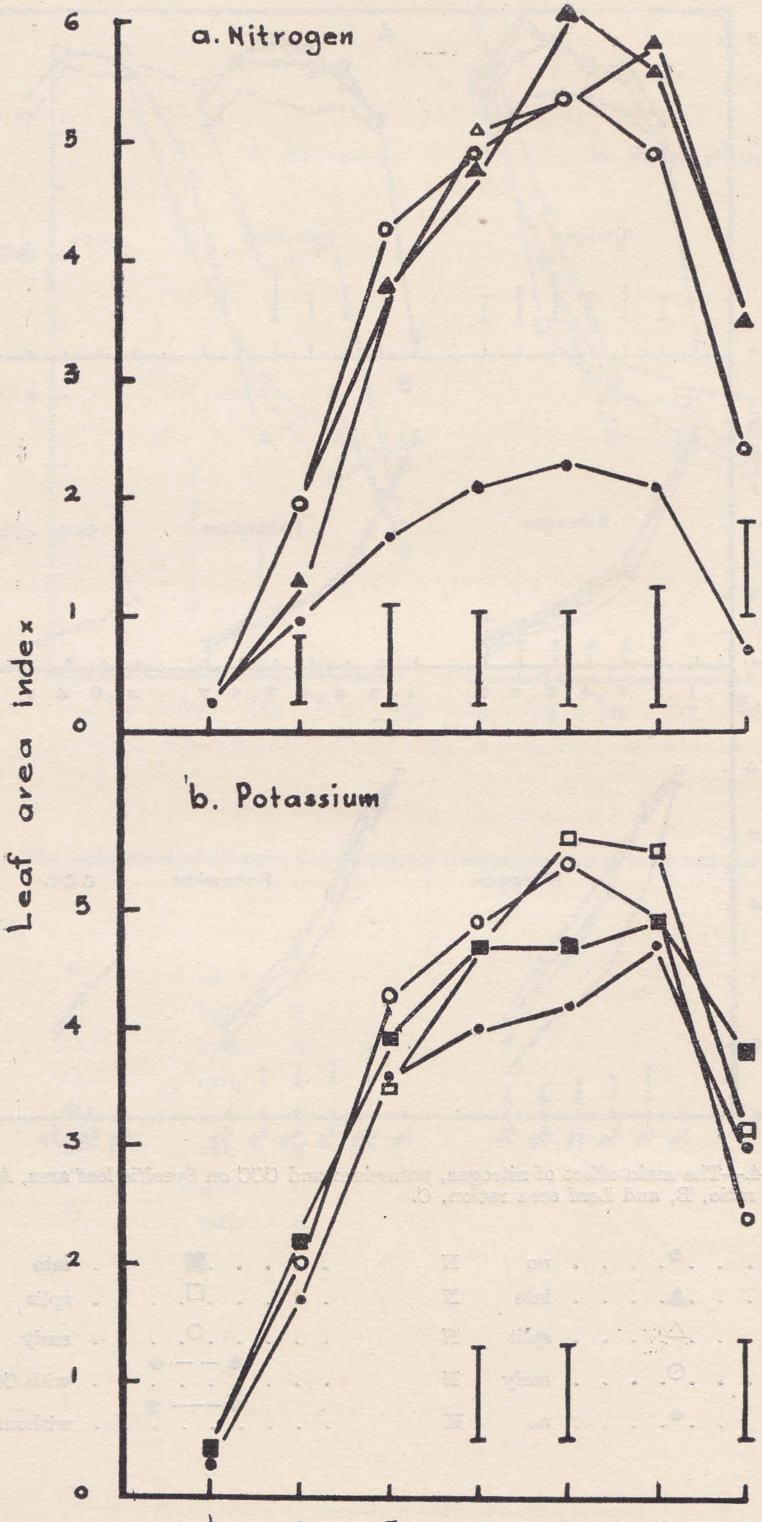

FIGURE 5

Fig. 5.—The effect of nitrogen and potassium treatments on leaf area index.

Legend

●	no	N	●	no	K
▲	late	N	■	late	K
△	split	N	□	split	K
○	early	N	○	early	K

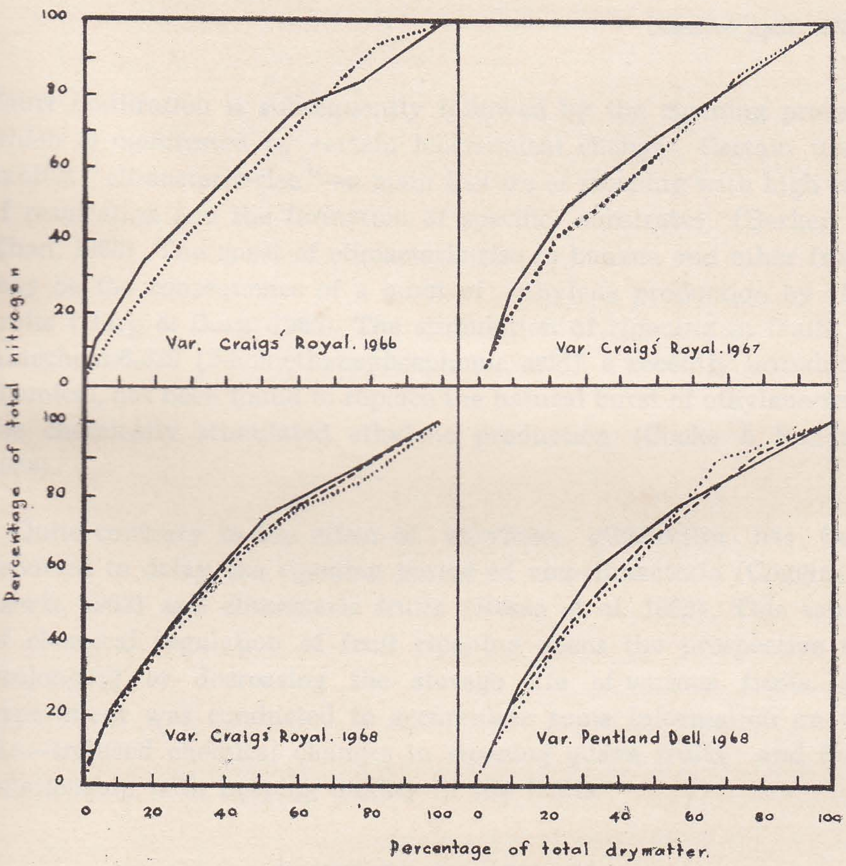

Fig. 6.—The accumulation of nitrogen relative to accumulation of dry matter.

Legend

—— early

. . . . . late

– – – split

Regulation of fruit ripening in Guava by gibberellic acid

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Fruit maturation is subsequently followed by the ripening process, which is manifested by certain biochemical changes, Certain fruits exhibit " climacteric-rise "—a main feature of ripening with high rate of respiration and the formation of specific substrates (Barker & Khan, 1968). The onset of climacteric-rise in banana and other fruits may be the consequence of a burst of ethylene production by the fruits (Burg & Burg, 1965). The stimulation of ripening in fruits by Amechem-6-329 (2-holoethanephosphonic acid), a recently introduced chemical, has been found to replace the natural burst of ethylene with the chemically stimulated ethylene production (Cooke & Randall, 1968).

Quite contrary to the effect of ethylene, gibberellin has been reported to delay the ripening period of non-climacteric (Coggins & Lewis, 1962) and climacteric fruits (Russo *et al.* 1968). This aspect of chemical regulation of fruit ripening opens the prospective for prolonging or decreasing the storage life of various fruits. An experiment was conducted to accumulate some information on the GA—induced chemical changes in ripening guava fruits, and their relationship with keeping quality of the fruits.

MATERIALS AND METHODS

Matured fruits of uniform extent, regarding morphological appearance, of Allahabadi Safeda and Pine Apple varieties of guava were collected after a rigorous selection from the horticultural

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garden of Punjab Agricultural University. Ludhiana, during September, 1968. One lot of 40 fruits of each variety was soaked in 200 ppm aqueous solution of gibberellic acid and another lot of 40 fruits in distilled water for two hours. This concentration of GA and duration of soaking were adjusted in some preliminary expriments prior to the start of the final one. After the treatment was given, fruits were placed wide apart in the iron trays having two layers of paper at the bottom at 25° ± 1C. Fruits were analysed at an interval of one day for ascorbic acid content by the methods of Bessey and King (1933). Water soluble sugars were determined in the flesh of fruits under carefully standardized conditions by adopting the method of Chalupa and Fraser (1968). Summation of each component of sugar is reported as the total soluble sugar.

EXPERIMENTAL RESULTS

Qualitative changes: Gibberellin-treated fruits markedly retarded the ripening process of both the varieties of guava. Treated fruits maintained an unripe appearance, whereas the untreated fruits began to show early ripening. Changes in fruit softening were quite apparent in treated and untreated fruits. On the eighth day after the treatment untreated fruits broke without much force, whereas treated fruits were in a good condition to resist the pressure while breaking.

Quantiative Changes: Allahabadi Safeda contained higher amount of ascorbic acid and sugars than Pine Apple. Untreated fruits of both the varieties showed a gradual decreasing tendency for dry matter and ascorbic acid content; abrupt reduction started on fourth day after the treatment. Gibberellic acid was found to slow down the degradation of ascorbic acid; and its content was invariably higher, even on the 8th day in treated fruits than the control. In the ripening process sucrose was found to be converted into hexose sugar as the substrate for respiration. Enhanced ripening process in untreated fruits was marked with the emergence of mannose. This sugar appeared later on in the treated fruits indicating, thereby, the involvment of gibberellic acid in the utilization of sugar in the ripening process.

Effect of gibberellic acid on some chemical constituents of two varieties of ripening guava

Variety	*Days after treatment*	*Dry matter* %	*Vit.C mg/100 gm*	*(Sugar(%) on fresh wt. basis)* *Sucrose*	*Glucose*	*Fructose*	*Galactose*	*Mannose*	*Total sugar* %
Allahabadi Safeda	0	19.3	185	4.60	4.40	1.20	0.50	—	10.70
	2 C	19.0	182	4.72	4.85	1.50	0.47	0.02	11.56
	GA	119.2	185	4.75	4.80	1.67	0.52	—	11.74
	4 C	18.6	170	4.05	3.91	1.85	0.66	0.02	10.48
	GA	19.0	182	4.72	4.76	1.72	0.61	—	11.81
	6 C	17.4	165	3.10	2.62	1.45	0.81	0.25	8.23
	GA	18.6	179	4.25	4.12	1.61	0.70	0.01	10.69
	8 C	17.0	155	2.82	2.51	0.72	0.62	0.31	6.98
	GA	18.2	170	3.91	3.25	1.34	0.70	0.06	9.26
Pine apple	0	18.5	168	3.82	4.21	0.85	0.61	—	9.49
	2 C	18.3	165	3.95	4.40	1.21	0.68	—	10.24
	GA	18.4	167	4.10	4.50	1.12	0.50	—	10.22
	4 C	17.5	159	3.42	4.60	0.75	0.41	0.01	9.19
	GA	18.0	163	3.80	4.25	0.92	0.51	—	9.48
	6 C	17.1	141	2.50	3.10	1.65	0.55	0.05	7.85
	GA	17.9	158	3.62	3.97	0.82	0.46	0.01	8.88
	8 C	17.0	120	2.25	2.75	1.25	0.30	0.12	6.67
	GA	17.6	147	3.41	3.61	0.72	0.44	0.03	8.21

* Average of five estimations in each case.

DISCUSSION

Certain fruits start showing the climateric rise just after harvest; this physiological process gets delayed when the fruits are intact with the tree which continues to supply some factor to delay the ripening process of the fruits (Burg, 1964). This behaviour is parallel to the contention on a changing sensitivity to gibberellin and ethylene in growing and ripening processes of fruits. Increasing amount of gibberellin in the developing fruits form a physiological sink for the attraction of metabolities towards the increase in the mass and volume of the fruits (Dennis, 1967; and Crane and Overveek, 1965). There is a decline in the natural content of gibberellin in fruits during maturation (Jackson and Goombe, 1966) culminating in the check in the translocation of food materials. At the end of maturity, the preparatory process for ripening starts in the fruit. Ethylene has been considered to be the major factor stimulating sensecence and ripening processes in various types of fruits (Burg and Burg, 1965). Convincingly, gibberellins have been found to act in the opposite manner to that of ethylene in various physiological processes (Scot and Leopold, 1967). On the basis of this observation, it can be argued that the process by which ethylene stimulates the chemical associated with ripening, can be negated by gibberellins. Delay in ripening of gibberellin-treated fruits of tomato (Dostal and Leopold, 1967) and banana (Russo *et al.* 1968) could be reversed by treating with ethylene. Thus gibberelin presumably acts in delaying the ripening of fruits by preventing some of the chemical processes initiated by ethylene.

SUMMARY

Effect of gibberellin-treatment on matured fruits of guava Var. Allahabadi Safeda and Pine Apple, exhibited a delay in the degradation of dry matter, ascorbic acid and sugar content during the ripening process. Results of the investigation depicted that a part of the ripening process in guava fruits can be deferred by gibberellin treatment for prolonging the storage period of the fruits.

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Fertizer experiments with maize
(Zea Mays) on a Bibile soil

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INTRODUCTION

With the advent of high yielding varieties, it has become necessary to investigate the nutrient requirements of cereal crops under local soil and climatic conditions. Supply of adequate nutrients is a pre-requisite to exploit the fullest expression of the high yielding genes in adapted maize varieties. The requirments of fertilizer for maize depend on whether it is being grown for grain or fodder/silage purpose (1). For the grain crop, while phosphorus and potash are of vital importance, very heavy applications of nitrogen are not desirable (1). It is considered that in maize grain production, nutrient balance is more important than the level of any single nutrient (2). This paper describes experiments carried out at the Bibile Experimental Farm during the period 1961-1963, to study the response of maize to N, P, K fertilizers under the soil and climatic conditions in Bibile.

MATERIALS AND METHODS

The experiment was a NPK, $3\times3\times3$ factorial in three replicates. The levels of N, P and K were as follows :—

Level	*No. lb/ac*	*P_2O_5 lb/ac*	*K_2O lb/ac*
0	0	0	0
1	40	30	15
2	80	60	30

Nitrogen as ammonium sulphate was given in two split doses, one half at planting and the other half six weeks later. Phosphorus and potassium as concentrated superphosphate and muriate of potash respectively were applied at the time of sowing. The variety used was Dixie 22. A plot size of 10 ft $\times$30 ft with a spacing of 2 ft in the row and 2 ft between the rows was used. Two or three seeds were sown per hill and thinned to one seedling per hill after two weeks. Earthing up was done after the application of nitrogen top-dressing at 6 weeks after sowing. Cobs were harvested at the end of $3\frac{1}{2}$ months after sowing. Statistical analysis was carried out only on grain yields.

3—J 13286 (4/70)

RESULTS

(a) Maha 1961-62

The soil on which the experiment was carried out was a sandy clay loam and had the following characteristics :

pH	.. 5.5
Nitrogen ..	.. 0.80%
Available phosphorus (Truog's)	.. 12.0 lb. P/ac.
Exchangeable potassium	.. 0.24 m.e.%
Organic matter ..	.. 1.20%

The main effects of N, P and K are as shown in Table 1.

Table I—Mean yields of maize in bu/ac

Level	*N*	*P*	*K*	*L. S. D.*
0	42.2	39.8	45.5	3.8
1	48.3	47.8	46.7	
2	50.1	52.9	48.4	

The results could be summarized as follows :—

(i) N gave a response significant at the 1% level. While 40 and 80 lb N/ac levels of N were significantly superior to the 0 level, there was no significant difference between the 40 and 80 lbs levels of N.

(ii) P too gave a response significant at the 1% level. The 60 lb P_2O_5/ac level was significantly superior to both 30 and 0 lb P_2O_5/ac levels and 30 lb P_2O_5/ac level was significantly superior to the O level of P.

(iii) K did not show a statistically significant response.

(iv) None of the two factor interactions was statistically significant.

(b) Maha 1962-63.

The trial was heavily damaged by wild boar and was abandoned.

(c) Maha 1963-64.

The soil was again a sandy clay loam with the following characteristics :—

pH	.. 6.0
Nitrogen ..	.. 0.11%
Available phosphorus (Truog's)	.. 20.0 lb. P/ac.
Exchangeable potassium	.. 0.25 m.e.%
Organic matter ..	.. 1.45

The yields were generally lower than those of Maha 1961-62. (Table 2 and 1).

Table 2—Mean yields of maize in bu/ac

Level	*N*	*P*	*K*	*L. S. D.*
0	33.2	26.6	34.3	4.8
1	36.9	37.5	33.2	
2	34.2	40.3	36.8	

The summary of the results is as follows :—

(i) P gave a response significant at 1% level. While the 60 and 30 lb P_2O_5/ac levels were significantly superior to the O level, there was no singnificant difference between the 60 and 30 lb P_2O_5/ac levels.

(ii) N did not show a significant response.

(iii) K did not show a significant response.

(iv) None of the two factor interactions was statistically significant.

DISCUSSION

Both these experiments showed good response to P fertilizer. This result is in direct contrast to that obtained at Maha-Illuppallama (4), where the direct response to P fertilizer was very small but a marked residual effect was observed. The residual effect of P in the present experiments was however not studied. A response of nearly 8 bu/ac in Maha 1961-62 (Table 1) and 13.7 bu/ac in Maha 1963-64 (Table 2) was obtained for an application of 60 lb P_2O_5/ac. These soils are low in available phosphorous and the observed response to P fertilizer is quite understandable.

A response of 5.9 bu/ac was obtained in Maha 1961-62 (Table 1) for an application of 40 lb N/ac. The yield increased on further addition of N, (Table 1) but the economics with higher levels of N may not be favourable with the variety of maize (Dixie 22) used in these experiments. This result is in close agreement with that reported from Maha Illuppallama (5), where no discernible advantage was obtained at levels exceeding 40 lb N/ac for maize under rainfed conditions. In Maha 1963-64, the response which was not significant was only 3.7 bu/ac, for the addition of first 40 lb N/ac (Table 2). The soil N was low and comparable to that of Maha 1961-62, and a greater response to N would have been expected. The rather inconsistent response to N in Maha 1963-64 may possibly due to biological variation.

Absence of a significant response to K was not surprising, considering the very satisfactory K status of the soils. However, an application of K at 30 lb K_2O/ac would be beneficial to counteract any lodging tendency that may be produced by high levels of N. Krantz and Chandler (3) observed that lodging was decreased by the application of K fertilizers when high levels of N were used.

CONCLUSIONS

Fertilizer experiments showed that on Bibile soils, maize responds to both N and P fertilizers. An application of 40 lb N, 60 lb P_2O_5 and 30 lb K_2O per acre could be recommended for Dixie 22 and similar or related varieties of maize on these soils.

ACKNOWLEDGEMENTS

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Response of plant growth regulators to mango

(Magnifera Indica L.)

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MANGO is one of the most delicious and choicest fruits of India. It is the king fruit of India and is gaining popularity and importance in the world market. In the advances of horticulture techniques with regard to mango industry, certain chemicals have got a great potentiality in the field of horticulture industry. Some plant growth regulators have been reported to induce better rooting than untreated ones (25, 28, 33) and their use has got a great impact on the commercial and industrial development of horticulture (26, 36, 39, 45, 46, 48, 51).

Although much work has been done on the various aspects in deciduous fruits viz ; grapes, apple, apricot, pear, strawberry etc., little has been attempted in case of tropical and subtropical fruits like mango, guava, citrus etc. Realizing the importance of such investigations in mango it was considered desirable to review the work done so far on the response of plant growth regulators to mango, and suggest possible steps which may prove useful in furthering the mango improvement programme. Plant growth regulators employed in the present discussion are listed as below :—

(i) beta—indoleacetic acid (IAA)

(ii) beta—indolebutyric acid (IBA)

(iii) beta—indolerpropionis acid (IPA)

(iv) alpha—Naphthaleneacetic acid (NAA)

(v) 2, 4—Dichlorophenoxyacetic acid (2, 4-D)

(vi) 2, 4, 5—Trichlorophenoxyacetic acid (2, 4, 5—T)

(vii) 2, 4, 5—Trichlorophenoxy propionic acid (2, 4, 5-TP)

(viii) Methylester of Naphthaleneacetic acid (MENA)

(ix) 2, 3, 5—Triiodobenzoic acid (TIBA)

(x) Gibberellic acid (GA)

(xi) 1, 2—Dihydro—3, 6-Pyridazine-dione (Maleic hydrazide) (MH)

(xii) Phenylacetic acid (PA)

(xiii) Alpha-Naphthaleneacetamide (NAD)

1. *Rooting* :—Hundreds of papers have been published on propagation with the use of plant growth regulators. Their effects have been recorded by Sen (48), Sen *et al.* (51, 52), Singh and Teaotia (66), Jauhari and Nigam (24, 26), Rao and Sreeramulu (45), Srivastava and Tewari (72), Rao *et al.* (36) and Kannan and Rao (29).

(*a*) *Cuttings*:—Results of various research workers (4, 10, 37, 40, 49, 60), data accumulated on harmones treatment of cuttings have proved that the beneficial effect lies with the proper concentration and time of application. Hussain (21) with NAA Acetamide "Rootone", Rao *et al.* (46) with IAA, IBA, PA NAD (0.25 or 0.5 per cent), and Thakurta and Dutta (76) with IAA (3 percent) observed a good success in the rooting of cuttings under mist conditions. Sen *et al.* (52) reported 70 to 80% improved rooting with the help of IBA 2,000 ppm. pretreatment in old cuttings.

Mukherjee *et al.* (37) applied IBA 5,000 ppm in lanolin paste at cut portions and found 50 per cent rooting, 40 per cent establishment of cuttings in comparision to 30 and 16.66 per cent in control, respetively. Further, Mukherjee *et al.* (38) used IBA (500 ppm) at the ringed point and left the branches attached to the monther tree and reported the maximum percentage of rooting and establishment of cuttings from one month old seedlings.

(*b*) *Air layering* :—Plant growth regulators have been used to get the maximum success in air layering (5, 9, 22, 23, 51, 55, 56, 69, 74). Singh (57) applied 1.0 per cent NAA on the cut spots of the branch and found 80, 40, 22, 20, 80, 70, 60, 60, 100, 60, 40 and 10 per cent succes in air layering in *Brindabani*, Krishnabhog, Sammerkand, Totapari Small, Kala, Anfas, Rataul, Dashehari, Machhali, P. S. Special No. 2, Banasi Langra and Fajri Kalan varieties, respectively. On the other hand, Ladin and Ruehle (31) observed no success in root formation with 1 per cent NAA. However, it is suggested that the success of propagation depends upon the best operation perfomed in the ideal conditions of temperature and humidity.

Srivastava (71) reported 100 per cent success of air-layers with the treatments of NAA (5,000 and 10,000 ppm) and mixtures of IBA and NAA. Mukherjee and Bid (36) in their trials found that IBA (10,000 and NAA (5,000 ppm) induced 100 per cent rooting and the corresponding survival rates of layers up to one year were 95 and 90 per cent, respectively.

Basu *et al.* (3) studied biochemical changes in the root forming regions at 4 stages—ringing, pre-callusing 8 days later, callusing 9 days after ringing, and root emergence 34 days after ringing, with and without IBA treatment and reported increase of total carbohydrates in untreated layered shoots and in those treated with 3,000 ppm IBA. Concentration of arginine + histidine in wood fell sharply in treated and control shoots while, Alanine increased in bark and wood until pre-callusing stage in untreated layers and the callusing stage in IBA treated layers and fell steadily thereafter.

(c) *Nursery Stock:*—Kannan and Rao (29) immersed mango seed stones in GA solutions and reported that GA 500 and 1,000 ppm gave graftable plant size within 2 to 2 1/2 months of stones sowing. Immediate increase in growth rate of treated seedlings was also recorded. Thomas *et al.* (77) found an increase in plant height with GA 300 ppm treatment. Treated seedlings were ready for budding at the age of 7 months as compared to control which took 12 months.

(d) *Bud take:*—Gur (19) reported the effective response in 'bud take' by immersing the bud wood into 200 ppm solution of IAA. Further Gur and Samish (20) found the increase success in 'bud take' by the application of IAA paste on the incision of budding.

2. *Breeding:*—It has been found that foliar sprays of 2, 3—Dichloro-isobutyrate applied before and during meiosis of the pollen mother cells has no effect on floral development. NNA, IAA and IBA sprays during early stages of floral differentiation did not affect the total number of flowers produced or the proportion of perfect flowers (18).

3. *Alternate bearing and growth:*—Singh (58) sprayed GA 50, 100 ppm and MH 0.4-0.6 per cent on mango shoots and suggested, on the basis of results obtained, that a crop may be taken by the use of GA even in 'off' year. Singh and Singh (62) applied 2, 4-D, 2, 4, 5-T, NAA and MH in soultion form and reported that 2, 4, 5-T significantly reduced fruit yield in 'on' year with a small compensation in the succeeding 'off' year. Some auxins are produced in the leaves and are transported to the apical meristems. The role of Gibberellic acid and other plant growth regulators in flowering is an important aspect and these are also related with the auxins produced in the plants. NAA 50 ppm and MH 50,500 and 5,000 ppm treatments induced the emergence of mixed panicles which are required for regular croping (50).

Singh and Singh (59) reported that TIBA in lanolin paste applied at the base of fruiting panicles, Kinetin in lanolin paste applied directly to lateral buds and girdling below the apex failed to induce growth in laterel buds. Growth substances were translocated from fruits to shoots specially in early stages when they were produced in large amount in fruits. Kachru *et al.* (27) applied GA 10^{-1}, 10^{-2}, 10^{-3} and 10^{-4} in lanolin paste on buds in 'on' year on 15th October, 1968 and found that 10^{-1} MGA_3 completely inhibited flowering and treated shoots produced vegetative growth in the month of March, 1969. 10^{-2} 10^{-3} and 10^{-4} MGA_3 also suppressed 75, 17 and 11 per cent flowering, respectively. It is suggested that complete inhibition by higher concentration of GA_3 could replace the mechanical deblossoming for getting regular yields. Mati *et al.* (1969) applied B-Nine and Cycocel at 1,000, 2,000 and 4,000 ppm in Baramasi and Langra varieties and reported that B-Nine and Cycocal, significantly increased flowering in both the varieties. Cycocal increased fruit set as well but B-Nine although significantly increased flowering but did not show any benificial effect on fruiting.

4. *Sex ratio:*—Expression of sex and sex ratio play a considerable role in the ultimate effect of fruit set and crop yield. Certain plant growth regulators have been found to be useful for inducing favourable sex ratio from the point of view of the beneficial cropping (61). Application of NAA 50 and 100 ppm spray 6 times on whole plant of Kalapady variety, reduced number of male flowers per female flower to 14 and to 9, respectively in comparison to 20 in control (35).

5. *Pollen viability:*—Singh (65) tried 10, 20 and 30 ppm of IAA, IBA, NAA, 2, 4, 5-T, GA, Colchicine, Boric acid and Borax in combination with 25 per cent sucrose solution and reported that plant growth regulator like IBA at 10 ppm had increasing effects on pollen germination and pollen tube growth.

6. *Fruit setting:*—Initially there were considerable differences in the effects of growth substances on fruit setting in mango. The effects were transmitary and at maturity there was no difference among the treatments (73). However, Singh *et al.* (61) used NAA 200, 400 ppm and MH 200, 400 and 800 ppm to increase the percentage of perfect flowers in the varieties *Janardan Pasand* and *Baneshan.* NAA 200 ppm was found effective and it also increased 3 to 5 times fruit set per panicle in *Baneshan* variety.

7. *Fruit development and fruit drop:*—Chacko *et al.* (6) observed in chromatographic experiments that at least 3 compounds with the

Gibberellin activity were found in developing mango fruits but none of them was identical to GA_3. Further they reported that N^6-Benzyladenine in addition to auxin and GA are necessary for parthenocarpic fruit development in mango.

The actual metabolic role of plant growth regulator in tissue of the Abscission Zone is still a moot question. It is believed that the life of the tissues of the abscission region is prolonged and consequently is seems that whole zone becomes healthy and develops potentiality to bear the load and regists the abcission layer formation. A considerable check in fruit drop in mango had been reported by the use of plant growth regulators (14, 15, 16, 17, 34, 42, 44, 53, 54, 63, 67, 70. 80). The main aim of drop-stop is to get the maximum yield by the ultimate retention of fruits in the panicles. Aqueous sprays of different concentrations of NAA, GA and 2, 4, 5-T applied at the begining of bloom, at full bloom and at the pea stage of fruit, after setting in *Langra* variety gave the significantly superior results to control. However, the highest fruit retention in all the three stages was found in case of NAA 5 ppm treatment. Single and double spray of 2, 4, 5-T at 25 ppm and single spray of GA at 100 ppm gave significant findings and highest fruit retention in *Dashehari* (75).

IAA at 15 ppm, IBA at 5, 10 ppm, 2, 4-D at 5, 15 ppm, 2, 4, 5-T at 10, 30 ppm and PF at 25 ppm were found promising in controlling the preharvest drop when applied 60 days before the normal harvest in *Bangalora* (1). Treatments of 2, 4-D at 30 and 40 ppm reduced drop up to 50.9 and 52.8 per cent respectively in *Neelum* (43).

The various plant growth regulators showed significant results on reducing fruit drop. 2, 4-D proved to be the best and gave a fruit retention of 56, 83, 84 and 83 per cent under 20, 40, 60 and 80 ppm. respectively (64). It was found that NAA at 15 ppm and 2, 4-D at 10 ppm increased fruit retention from 18.00 to 20.79 per cent in *Dashehari,* while in *Langra* only 2, 4-D at 15 ppm increased fruit retention from 21.98 to 23.15 per cent over control (68). Chadha (7) reported the most beneficial results with the use of NAA and 2, 4-D (20-60 ppm) in the period somewhere between the mid-April and Early May. Chadha and Singh (8) used NAA, 2, 4-D and 2, 4, 5-T (20. 40 and 60 ppm) and reported that there was significant reduction in the fruit drop in 2, 4-D treatment. Roy *et al.* (47) used NAA and 2,4-D (1-15 ppm) in *Gulab-Khas, Himsagar, Langra* and *Bombai* varieties and reported that 5-10 ppm of both the substances considerably reduced the fruit drop.

8. *Quality:*—The industrial value of the fruits depends on the high quality of the fruits produced. Research workers have found the remarkable effects of hormones on the development and quality of mango fruits (8, 11, 13, 41).

(a) *Ripening:*— Application of the dilute solution of growth regulators, applied to fruits before the commencement of storage, has shown retardation in ripening (78). The retardation in the changes of skin colour was closely associated with the ripening and it was more pronounced in the 2, 4, 5-T (1,000, 1,500 ppm) treated fruits than with MH-40 (1,000, 1,500 ppm) (12). Kennard and Winters (30) reported that 2, 4, 5-TP at 800 ppm applied 3 weeks after blossoming hastened maturity by 2 weeks, while treatments 6 weeks after blossoming hastened fruit maturity by one week and reduced fruit size in case of *Amini* variety.

Mature fruits treated with 2, 4 5-T and MH-40 at 1,000 and 1,500 ppm revealed that the effect for increasing the storage life was most promising when 2, 4, 5-T was applied at 1,000 ppm (13).

(b) *Ascorbic acid:*—Increased content of ascorbic acid was recorded (30) in the pulp of fruit treated with 2, 4, 5-T. Date (11) reported increased content of ascorbic acid with MH-40 at 1,000 ppm and 2, 4, 5-T at 200 ppm and mixture of MH at 1,000ppm and 2, 4, 5-T at 100 ppm. Similar observations have been reported by Chadha and Singh (8) with 2, 4-D at 40 and 60 ppm and by Arora and Sinh (2) with NAA, 2, 4, 5-T and 2, 4, 5-TP in *Dashehari* mango.

(c) *Total soluble solids:*—Arora and Singh (2) applying 2, 4-D, NAA, 2, 4, 5-T, 2, 4, 5-TP Singly and in the form of mixture on *Dashehari* and *Langra* mangoes during the development of fruits period observed an increase in the content of total soluble solids. Chadha and Singh (8) on the other hand reported that total soluble solids content remained uneffected when NAA, 2, 4-D and 2, 4, 5-T was applied at 20, 40 and 60 ppm in *Langra* variety.

(9) *Parthenocarpic fruit:*—Venkataratnam (79) found that after removing staminate flowers and leaving only 20-30 bisexual flowers in a panicle and treating the emasculated flowers with NAA at 10 ppm, increased fruit set in three varieties of mango. It was also observed that the growth of embryo was completedly inhibited in the parthenocarpic fruits.

10. *Seed germination:*—The germination of mango seeds when treated with 2, 4, 5-TP was reduced significantly and the time required for seedling emergence was also prolonged (30). Adverse effects of

higher concentrations of 2, 4-D and 2, 4, 5-T on germination of mango seeds were recorded (2) in *Dashehari* and Langra but 2, 4, 5-T (10 ppm) proved beneficial in case of *Dashehari* only.

It would, thus, appear from the foregoing review that the present day knowledge on some of the aspects is rather scanty. It is also evident from the above that the results on some of the aspects are widely varying. Therefore it is suggested that well planned researches with plant growth regulators on the various aspects should be conducted in the different climatical regions and beneficial recommendations should be given for the development of mango industry.

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