EFFECT OF SPACING AND SEED TUBER SIZE ON THE YIELD OF POTATO

BY

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I certify that this thesis entitled " Effect of spacing and seed tuber size on the yield of Potato " submitted in partial fulfilment for the award of degree of Master of Science in Agriculture (Agronomy) of the Orissa University of Agriculture and Technology, Bhubaneswar, is a record of bonafide research work carried out by Sri Golak bihari Sahoo under my guidance and supervision and that no part of the thesis has been submitted for any degree or diploma or published.

It is further certified that such help or source of information as has been availed of during the course of investigation, has been acknowledged by him.

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List of Abbreviations.

M.m. - Millimeter.
C.m. - Centimeter
m. - Meter
Sq.m. - Square meter
ha. - hectare
Gm. - Gram.
Ac. - Acre
Kg. - Kilo-gram
c.c. - Cubic centimeter
Sq.cm. Square centimeter.
Oz. Ounce.
No. Number.
C.D. Critical difference.

N - Nitrogen.
K - Potash
P - Phosphorus
C - Carbon.
Mn. - Manganese
F.Y.M - Farmyard manure.
C.A.N. Calcium ammonium nitrate.
% - Percentage
,000 - 1000
Fig. - Figure.
Sig. - Significant.

INTRODUCTION.

The problem of feeding ever-increasing teeming millions of India is massive in-deed and cereal economy which is mostly viewed to be associated with the backwardness of a nation cannot solve this food problem. Industrially advanced countries have given, besides cereals, an equal place to potato in their daily diet. Percentage consumption of cereals and potatoes annually in India are 97.43 and 2.57 respectively as against the corresponding figures of 35.95 and 64.05 in an advanced country like Germany, and 86.67 and 13.33 in an under developed country like Turkey.

The importance of potato in our nutritional programme is gradually gaining ground from the view points of its food values and the industrial essential products it supplies. In the present set-up of rural economy of our country the ability of a crop to produce food quickly and continue to do so over a long range of period is a unique advantage. Hence the potato by virtue of its inherent potentiality to solve the tremendous food problem of our country, demands its due place.

Viewed under the above perspective the fact remains that to step up the per acre yield of potato in India a complex of variable factors such as good disease-free varieties, optimum seed size and spacing, right type of soil, judicious manuring, irrigation and plant protection are to be tapped.

Of all these factors, the size of the seed tuber is an important one having profound influence not only on the yield and grades in the produce but also on the quantity of seed required to sow a particular area. As seed is generally a costly item, higher seed requirement tends to increased cost of production. Tingey and George (1928) have reported that size increases the growth rate and yield. So the use of the smallest quantity of seed commensurate with the maximum net returns is to be welcome in potato cultivation.

The amount of seed tuber per hectare varies not only due to their size but also the spacing of the rows and that of tubers in the rows. If the rows are too closer, the requirement of the seed tubers greatly increase and the intercultural operations like hoeing, earthing-up are adversely affected.

On the other hand, if the spacing is too wide the yield is greatly reduced. The spacing of tubers in the individual row also influences both the economy in the use of seed and the ultimate yield. The close or too wide a spacing may depress the yield, the former by inducing unhealthy competition between the plants and the latter by causing sparse population.

So the most profitable combination of the seed size and the spacing will be that which by way of making the most efficient use of the available plant nutrients and moisture in the soil yields maximum.

Considerable variations do exist in the planting space and size of seed tubers used for production of potato in the different countries and production areas of the same country. Most published research results in our country and abroad do provide schedules of these factors applicable to particular localities as the results obtained at one place may not be applicable under different agro-climatic conditions.

But in Orissa where there are wide variations in the size of the seed tubers planted and planting space followed and with an average low yield of about 87 quintals per hectare averaged over a total area of 10 thousand hectares devoted to potato, no salubrious research result on optimum size of seed tuber and plant spacing is reported. Therefore, the increasing importance of seed tuber size and planting space which govern the yield, has entered into the production picture these days.

With the above facts in the background it was felt proper to investigate to provide a bit which is expected to go a long way in fulfilling a long-felt need of potato growers. The dissertation presents the results of the studies of field experiment conducted in Agronomy Division Farm, Utkal Krushi Mahavidyalaya, Bhubaneswar during Rabi season, 1963-64 to assess the optimum seed tuber size and spacing in production of potato.

REVIEW OF LITERATURE.

In most spheres of human activity, it is the knowledge of past achievements and current trends that provide an admirable base for future progress. A brief review of literature collection contained in this chapter, designed to afford an idea of the considerable body of work done in India and abroad on potato on the effect of spacing and seed tuber size on the growth, yield, and size of potato tuber is likely to prove of value in facilitating ready reference.

Potato Soils :

The potato can be grown almost on any type of soil, (except alkaline, though it is tolerant even to saline conditions). However, it thrives best under sandy or sandy loam soils. Most of the crops, particularly erect cereal crops tend to lodging in soils with a poor texture. A soil type which will bind the roots and keep the plants erect, more so under irrigated conditions, is necessary for cereal crops. The potato has no such fad. Unlike cereals, it builds food under ground and prefers a loose soil type, so as to allow the root system to spread and the young developing tubers under ground to grow freely. Excellent potato crops, can, therefore, be secured under a river bed system of cultivation. On the other hand, potato is by no means allergic to heavier types of soils.

suitable for rice or jute cultivation. Rice - potato and Jute - potato are established rotations practised in West Bengal and Orissa (Anon. 1961).

According to Schachtschabel (1956) of West Germany the highest potato yield could be obtained from a loamy sandy soil having a pH ranging from 6.0 to 6.5 with the presence of an adequate amount of Mn. Further he elucidates that the optimum pH range should be 5.5 to 6.0 for sandy soils which have been abundance of humus but poor in clay and Mn. contents.

It was reported from Netherlands that the crops of the variety Bintje grown on sandy soils contained a higher percentage of oval tubers than those grown on clay soils, irrespective of the shape of the seed potatoes used (Anon., 1957).

Effect of spacing on :

i) Germination - From a carrot experiment Harrington (1951) at Davis showed that the different spacing had no significant effect on percentage of germination.

ii) Number of leaves - Singh and Ahlawat (1955) stat that the spacing 4", 7" and 10" had no significant effect on the maximum number of leaves formed per plant.

iii) Height of the plant - Singh and associate (loc.cit) showed that the different spacing had no effect on the height of the plants.

iv) Size of the tubers - Wide spacing reduced the yield of seed and chat potato but increased the average size of large ware tubers (Bates, 1935; Findlay and Sykes, 1936). Singh and Mukankar (1943) reported that the increase in spacing distance decreased the yield of both large and small potatoes. Results of two comparative trials on spacings as experimented at Terre Marocaine(1952) show that the spacing of 70 cm. x 40 cm. gave lower percentage of smalltubers as compared to wider spacings of 60 cm. x 45 cm. and 100 cm. x 35 cm. Davies (1954) concluded that as the mean spacing increased, the yield of tubers above 2¼" for two consecutive seasons and above 2¼" for a single trial decreased. The effect of this on the total yield was offset by the increased yield of larger tubers as the mean spacing increased.

Flamini (1957) stated that the largest tubers were obtained from the lowest plant densities and vice-versa. From the report of Department of Agriculture, New-South Wales it was noticed that the close planting lowered the proportion of over sized tubers significantly (Anon., 1958). It is reported from Denmark in 1958 that the spacing of 63 cm. x 20 cm. and 74. cm. x 17 cm. resulted in the highest proportion of seed tuber and followed by the spacing of 84 cm. x 20 cm. Spacing of 63 cm. x 40 cm. 74 cm. x 34 cm. resulted in the yields containing similar proportion of tuber of different sizes and a considerable increase in the proportion of tubers greater than 55 mm. diameter, compared with other treatments. According to them distance between plants in the row had much greater effect on the proportions of tubers of different sizes than did the distance between the rows. They further mentioned that the plant population greater than 40,000/ha. resulted in an increase of the proportion of small tubers.

Chaudhuri and Chaudhuri (1958) noticed that the spacing of 24" x 5" although gave highest yield but produced under sized tubers. It was reported from Winconsin that when potato rows were spaced 18" apart, 44% of the tubers were of seed size (1.5" - 2.5") while at the standard row-spacing of 3',only 29% of the tubers were of this size (Anon.,1959), Keller, <u>et al</u> (1961) observed that the small grade seed tuber yielded the higher proportion of ware and class B seed tubers. Conducting the experiments for two seasons Bremner, <u>et al</u> (1952) found that the proportion of the total produce in the ware grade increased as the spacing distance increased. Tiwari (1962) reported from a singular trial that the percentage of tubers larger than 1.25" in diameter was the lowest but the proportion of the tubers of 0.75" - 1.25" in diameter tended to be the highest at 6" when compared with 9" and 12" plant spacings.

v) <u>Weight of tubers</u> - Mc.Cubbin (1955) reported from Florida that the average weight of tubers was decreased as the spacing decreased.

vi) <u>Number of tubers</u> - From the results obtained from long duration experiment spread over 10 years in

Florida Mc. Cubbin (1955) emphasized that as a given size was spaced closer in the row, the number of tubers produced per plot increased. Contradicting this finding Roer (1957) concluded than increase in spacing raised the number of tubers per hill.

vii) Yield of tubers - Singh and Wakankar (1943) found that the increase in spacing distance decreased the total yield. There was no significant decrease in the yield when the spacing distance was increased from 6" to 9" but the yield decreased significantly when the spacing distance was increased to 12". Similar results were obtained by Bates (1935) and Findlay and associate (1938) who stated that with the increase in spacing the total yield decreased.

Harrington (1951) showed from the carrot experiment that 15" as well as 10" spacing gave significantly higher yields of carrot than 30" spacing which is in conformity with results reported earlier by various authors for potato yields.

Singh (1952) concluded that close spacing gave more gross yield than the wider spacings. From two comparative trials on spacing at Marocaine (Anon) reported that the spacing 80 cm. x 45 cm. and 70 cm. x 40 cm. gave the highest yield per plant and per unit area respectively (Anon 1952). According to Rieman and others, (1953) 21" spacing in rows of 3' apart was the best, as it produced the highest yield of U.S.I size A and large (Jumbo) potatoes, closely followed by 18" and 24" spacings.

In Norway, Ingebrigtsen (1953) found that the highest tuber yield was obtained from 50 cm. row spacing being 2353 Kg./Hecare. The average tuber yield for spacing of 60 cm. and 80 cm. were 2245 Kg. and 2033 Kg./decare respectively. The mean total tuber yields of 2195, 2005,1867,1765,1940 and 1631 Kg./decare were obtained due to 15,20,25,30,35,40 cm. of plant spacings in row respectively. Di az de Mendivil and others(1953) found in Spain that the spacing 65 cm. x 30 cm. gave the highest yield where the distance between rows was kept at 65 cm. and the distance between the plants in the row varied from 30 to 70 cm. Singh and Ahlawat (1955) recorded 7" plant spacing to be the best giving higher yield than both 4" and 10" spacings. 2' spacing between rows proved to be better than 1'4" and 1'6" spacing at C.P.R.I.,Patna (Anon., 1955). Roer (1957) reported that the highest total yield at a spacing of 20 cm. and net yield at 30 cm. was obtained. Closer spacing was more favourable in years of good yield.

From Bhanjang in West Bengal (Anon.,1957) it was reported that 18" x 6.6" gave the highest yield. By reducing the spacing in the row from 20 cm. to 10 cm. an increase in potato yield to the tune of 36 % was obtained in Sicily (Jannaccone, 1957). The closer spacing increased the total yield but decreased the yield of ware tubers, Haugdal (1957) in Norway and Ariyanayagam (1958) in Ceylon. From Denmark in 1958 it was reported that greater distance between rows than the normal 63 cm. can be used without entailing great yield reductions with a given plant population per unit. Plant population greater than 40,000/ha. resulted in decreasing in net tuber yield. Chaudhuri and Chaudhuri (1958) observed that the spacing 24" x 5" gave the highest yield. Reestman and Dewit (1959) reported from Netherlands that in case of wide planting a close relation existed between the number of stems per unit of soil surface and the yield. Fla-mini (1959) stated that the total yields increased as the density increased from 1.7 to 6.7 plants/sq.meter.

From a singular potato trial in Belgium Congo, it was observed that the spacing of 50 cm. x 50 cm. (40,000 plants/ha) gave the highest yield. (Anon., 1959) Svensson (1961) obtained the increased yield with decreased row-spacing. He also confirmed that the gross yield of potato was increased by increasing the planting rate. Keller, et al. (1961) concluded from 6 experiments in Switzerland that yields from two grades i.e. 32-35 mm. 40-55 mm. diameter were equally high at normal harvesting date. His statement was contradictory to that of the previous workers.

Conducting experiments for 3 consecutive years to find out the optimum rows-spacing for hills of Himachal Pradesh, Patil (1961) confirmed that a row spacing of 16" resulted in a higher yield than that of 20" or 24". Singh, et al. (1961) reported that the gross yield of potatoes increased with the closeness of spacing. Kurihara and Tabata (1962) found in Japan that the tuber yield / unit area increased in proportion to the decrease of the spacing area. Further he noticed that the tuber yield per unit area varied with the branching habits of potato varieties used.

viii) Specific gravity - Chandra (1961) reported that the specific gravity of the potato tubers produced was slightly higher at closer spacing than the wider ones.

ix) Tuber quality - It was reported from the Department of Agriculture, New South Wales (loc.cit.) that the close planting decreased the amount of hollow heart and growth cracking. Ariyanayagam (1958) found that the smaller the tuber, better it was stored. Svensson (1961) observed that the row distance did not affect the cooking quality of the potato tubers produced.

Spacing recommended - From I.A.R.I. experiments Verma (1953) concluded that the spacing was to be adjusted according to the variety. A row spacing of 2' for Phulwa whose stolons spread out quite considerably and a row spacing of 1½' for variety Up-to-date where tubers formed close to the stem were optimum. Further, he stated that 9" tuber spacing was the best in general but variation might be due to variety. Row spacing of 60 cm. and plant spacing of 20 cm. - 25 cm. were considered the most desirable (Ingebrigtsen, 1953). Boyd and Lessels (1955) recommended 27"-29" as row spacing and 17"-18" as plant spacing. Roer (1957) reported that a spacing of 40 cm. was as good as 50 cm. under favourable conditions. As recommended by Purewal, et al. (1957) the optimum spacing of a colocasia plant under the Punjab conditions was either 1½' x 12" or 2' x 9" which gave the economical returns. Linares (1958) in Central Venezuela concluded that potatoes should be square planted at 15 cm. - 20 cm. apart.

Effect of tuber grade on :

1) Germination -

Welch (1917) noted that the emergence of sprouts was independent of the pattern of seeding but was determined wholly by size of the seed pieces. Wakankar(1944) observed that large seed pieces produced greater number of sprouts. Harrington (Loc.cit) from carrot experiment showed that the difference in size of root carrot had no significant effect on germination percentage.

Singh (1952) stated that the sprouts from small seeds emerged later, were fewer in number and had slower early development. Werner (1954) reported that the large cut setts produced the best stand but there was a steady decrease in final stand of plants, as the size of the seed potatoes increased. The sprouts from larger seeds emerged more rapidly and showed greater vigour than those from smaller seed tubers, Roer (1957) in Norway, Munster and Keller (1958) in Switzerland.

ii) Number of leaves - Suri (1963) reported from his systematic study that as the size increased the number of leaves per hill increased in early stages of growth. In case of small size seed the number of leaves increased in later stages to a greater extent as compared to increase in case of larger seeds.

iii) Height - Suri (loc.cit.) reported that the height increased as the seed size was increased from ½" to 1½" diameter of tubers.

iv) Number of stems and branches - Bates (1935) argued that the larger seed tubers produced greater number of plants per hill. Kapoor (1951) noticed that the weight of tops increased as the seed size was increased. Werner (1954) observed that the number of stem per cut sett increased as the weight of setts increased and also as the weight of seed potatoes decreased. Roer (1957) reported that the number of stems per hill increased with increasing the size of seed.

v) <u>Size of the tubers</u> - According to Bates (1935) the large seed pieces reduced the individual size of the tuber and small pieces produced larger ones. Findlay and Sykes (1938) demonstrated that seed potato gave rise to big sized tubers as against ware tubers. Large seed pieces produced maximum net yield of ware potatoes and proportion of seed was equally high. Seed size did not influence the yield of large ware tubers but average size of the tubers produced was the largest from the small seed pieces. Singh and Wakankar (1943) reported that large seed produced the minimum and small seed the maximum percentage of large seed.

According to Kapoor (1951) the increase in size of seed tubers caused a fall in potato size. Verma (1953) from I.A.R.I. experiments concluded that bigger the seed tuber, the lower the percentage of large sized tubers in the produce. Werner (1954) stated that more large tubers were produced by small cut setts than by large setts. Regarding the whole tubers as seed material he obtained some contradictory results that small seed potatoes produced more tubers of some what smaller size than did the large tubers. From West Germany (Anon.,1957) it was reported that with increase in size of seed potato, the percentage of over-sized potatoes decreased.Trials over several years in Peru, indicated that small seed tubers yielded a smaller proportion of potatoes for consumption than did the large tubers; this proportion increased directly with the size of the seed, (Llaveria and Montalvo, 1958). From Poland it was reported by Birecki and associate (1963) that small seed tubers yielded the least seed size tubers. Chandra (1961) showed that increase in seed piece size increased the proportion of the yield in 2.25" - 3.25" size class. Bremner, et al. (1962) noted that the greater proportion of the produce from small seed fell in the ware category.

vi) Weight of tubers - Kapoor (1951) reported that each increase in tuber size was followed by a corresponding rise in the weight of tubers. Mc. Cubbin (1955) observed that as the size of seed increased the average weight of tubers decreased. Roer (1957) noticed that the average tuber weight decreased as the seed size was raised.

vii) Number of tubers - Seed potato resulted in lesser number of tubers (Findlay and Sykes, 1938). Wakankar(1944) reported that large seed pieces produced a greater number of tubers per hill. Singh (1952) showed that the tuber number decreased with decrease in seed size. Werner (1954) reported that more large tubers were produced by small cut setts than by large setts, the smaller seed potatoes produced more tubers (of some what smaller size) than did the large tubers. Roer (loc.cit) concluded that the number of tubers per plant increased as the seed size and number of stems increased. The tuber numbers per stem decreased with increasing numbers of stem per plant and the numbers of tubers decreased with increasing seed size. The number of tubers per hill increased as the size of seed potato was increased from ½" to 1½" (Suri, 1963).

viii) Yield of tubers - Salaman (1923) reported that the larger the seed tuber, the greater is the gross yield produced. Singh and Wakankar (1943) working at Banaras concluded that the use of small and medium sized seeds gave significantly higher net yields than the use of large seeds. From a popular leaf-let by Mitra and Bose(1947) after conducting field experiments at Kanpur it is observed that the per acre potato yields could be significantly raised by resorting to the use of a larger seed size. However, they concluded that to employ large sized seed was not practicable in the absence of adequate cold storage facilities. Burton (1948) showed a direct correlation of seed size with the yield.

By increasing the seed size of Darjeeling Red Round variety, the ultimate tuber yield per hill was increased (Kapoor, 1951). Singh, et al. (1952) found that increase in size of potato seed produced linear and progressive increase in the yield of tubers. He also found that there was no perceptible difference between the yields produced from the two lower categories of 1" and 1½" diameter, sizes lower than 1" diameter category decreased yield and were uneconomic. Net average tuber yields of 1708, 1909 and 1913 Kg./decare were obtained by using 25, 50 and 100 gms. of seed potatoes in Norway (Ingebrigtsen, 1953). Di Az de Mendivil, et al. (1953) reported that the largest tubers gave the highest yield. Similar results were obtained by Antchev (1959) in Yugoslavia. Luijendijk (1954) stated that the increased size of seed tubers increased the saleable ware potatoes. He got 41,000 Kg./ha. from largest grade of 45 - 55 mm. diameter and 33,550 Kg./ha. from smallest grade of 25 - 28 mm. diameter. Werner (1954) showed that the average yield in the 5 year experiment were increased by 10 bushels/acre by doubling the size of the cut setts from 22 gm. to 44 gm. and for a fixed size of seed pieces, the yields were increased by approximately 12 bushels/acre by decreasing the average size of the seed potatoes from 155 gm. to 28 gm., the lowest average yields occured when tubers weighing 155 gm. were cut into 8 pieces and the highest when the tubers weighing 50 gm. were planted whole.

From the report of C.P.R.I. Patna (Anon., 1955) and that of U.P. (Anon., 1957) it was noted that the yield increased with increase in seed size. Montague and Ivins (1955) noticed that the larger seed tubers out-yielded more total yield and less percentage of ware grades (over 2.25" diameter). Mc. Cubbin (1955) reported that the increased in yield were obtained in most tests as the size of seed used was increased from 1 oz. to 2 oz. In West Germany it was recorded that with an increase in size of seed potato the crop yield was increased, (Anon., 1957). Similar results were obtained by Roer (1957) in Norway, Ariyanayagam (1958) in Ceylon, Chandra (1961) in U.S.A., and Singh, et al. (1961) in India. At Bhangang (West Bengal) it was found that the 1½" size tubers gave the highest yield of 40.75 mds./ac. compared to 25.03 mds./ac. and 20.36 mds./ac. from 1" and ¾" diameter tubers respectively. No significant difference between 1" and ¾" tubers was found (Anon, 1957).

Out of 75 experiments Jahnl (1959) concluded that the large tubers gave significantly better yields than small ones, irrespective of whole or cut seed potatoes. Flamini (1957) reported that the total yield was increased as the size of the seed potatoes were increased from 30 gm. to 120 gm. By increasing the weight of each sett. from 10 gm. to 20 gm., the yield increased by 58% (Jannaccone, 1957).

Chaudhuri and Chaudhuri (1958) observed at Burdwan (West Bengal) that seed tubers 1½" in diameter, 12 tubers to the lb. in combination with 80 lbs. N, 160 lbs. P_2O_5 and 80 lbs. K_2O/acre gave the highest yield. Bishop and Wright (1959) noted that the total yields of tubers were increased by increasing the sett weight. Patil (1961) found that 3 oz. seed piece gave significantly better gross yield than 1 oz. and 2oz. But the net yield (gross yield - seed used) was similar in 3 cases. Puri (1963) reported from his systematic investigation that the total yield increased as the size of the seed potato was increased from ¾" to 1½" diameter.

ix) Specific gravity - Chandra (1961) reported that the increase in seed piece size increased the specific gravity of the tubers produced.

x) Incidence of virus disease - Increasing seed size lowers the incidence of mosaic disease, specially in Phulwa variety both at Kanpur and Farrukabad, U.P. (Anon., 1955-56). It was reported from West Germany (Anon., 1957) that with increase in size of seed potato the percentage of virus diseased tubers harvested decreased. Birecki and Rostropowicz (1963) reported from Poland that from the stand point of virus diseases the use of seed tuber of moderate size (60 gm. to 70 gm.) offered the greatest security.

Tuber size recommended - Salaman (1923) recommended 1.5 oz. of seed size as the most economic seed. Tinely and Bryant (1939) showed that optimum seed weight was 2 oz.

(1¼" to 2½").Singh and Wakankar (1943) recommended small seed and Suri (1963) suggested 1" diameter seed tubers under Banaras condition. Mitra and Bose (1947) observed that 1" seed size was the economic. Verma (1953) opined that the most suitable size for Phulwa variety was between 1" - 1¼" diameter. Out of 56 field trials in Nether lands Reestman (1953) recommended the use of larger seeds to growers who required early lifting of of potato as the crops grown from larger seeds matured earlier. Average weight of tubers of certified seed was 2.5 oz. in 1950 (Boyd and Lessels, 1954).Linares (1958) stated that the best seed potatoes were whole potatoes of 40 gm. each. If cut tubers were to be used they should weigh 50 gm. each.

Effect of spacing-cum-grade on yield -

It was reported by Singh (1952) that a unit change in spacing, however, produced more effect on yield character than a unit character of seed size. Further he stressed that the closer spacing with large seed was risky. Roer (1957) noticed that in years of good yield a spacing of 30 cm. was the most economic with the medium sized seeds, other wise 3 widest spacings gave about the same net returns. With large seeds the widest spacing was the best especially in years of low yield. Chaudhuri and Chaudhuri(1958 concluded that 30" x 8" spacing in combination with 1½" tuber size gave large percentage of ware tubers.

The result obtained by Warren (1958) was that the whole or halved tubers 1.5 oz. in weight, planted 6" apart produced significantly higher yield of standard size seed tubers than did 1.5 oz. sett cut from tubers selected at random and planted 12" apart. From the trials over several years in Peru, Llaveria and Montalvo (1958) showed that the satisfactory results were obtained with a normal spacing of 30 cm. between hills where as several small tubers were planted per hill. They also stated that with the same weight of seed potatoes/ha; similar yields were obtained from planting small, medium and large tubers. Fedderson (1958) stated that the seed tubers weighing less than 1.75 oz., planted 9" apart in the row, yielded less than normal 2 oz. seed and were not suitable for seed production because of small number of stems produced.

Bishop and Wright (1960) showed that there was little difference in yields between 1 oz. setts spaced 7.5" apart and 2 oz. setts spaced 15" apart. They concluded that the large setts spaced 7.5" apart produced the highest proportion of under sized tubers. Tuber size was influenced more by spacing than by sett weight. As recorded by Keller, et al. (1961) the small grade seed tubers at the closest spacing yielded about the same as the normal grade at the widest spacing, but less than the normal grade at other spacings if harvested early. At the normal harvesting date, yield from both grades at the closest spacing were equally high, the small grade seed tubers yielded the higher proportion of ware and class B seed tubers. The results obtained by Patil (1961) was that 16" spacing with 3 oz. seed weight gave the highest gross yield in all the three years under study. The highest net returns were obtained with 24" and 1 oz. seed weight in 2 out of 3 seasons. As observed by Singh, _et al_. (1961) the net yields were in favour of large (1¼" - 1½") or medium sized seed (1" - 1¼") planted at 2' x 9" spacing. Small sized seed (¾" - 1") planted at a wide spacing (2¼" x 1') gave the highest proportion of ware tubers in the produce, whereas, for the production of predominately seed size tubers, large sized seeds (1¼" - 1½") were to be planted at a very close spacing (1½' x 6").

<u>Recommended spacing-cum-seed tuber grades</u> -

Highest net yield was obtained by Singh and Wakankar (1943) by planting small seed with 9" spacing. Reestman (1953) arrived at the conclusion that the practice of using 25 mm. to 28 mm. seed, closely spaced, was a safe one and recommended whenever financially advantageous. The plant population recommended by Luijendijk (1954) for conditions of Netherlands, for the 25 mm. to 35 mm., 35 mm. to 45 mm., 45 mm. to 55 mm. grade were 55, 45, and 35 thousands/ha. respectively. The grades of 35 mm. to 45 mm.

with 55,000/ha. and 45 mm. to 55 mm. with 45,000/ha.were the best for growing seed potatoes. Boyd and Lessels (1954) opined that the precise combination of seed size and spacing were of minor importance i.e. a grower should aim to plant at the optimum seed rate regardless of seed size. The optimum rate of planting at 1952 prices of 'A' and 'H' certificate seed was estimated to be 16 - 17 cwt./acre. Yield trials over several years indicated that the intermediate planting rate approximately 12 bu/ac. was the best. With this rate,close planting of small seed pieces was preferable to planting seed pieces of double the weight at twice the distance. (Werner, 1955). Mc.Cubbin(1955) reported on the basis of yields and crop price figures that the highest returns / acre was obtained by planting 2 oz. seed at 8" spacing. In California, Bishop and Wright (1960) stated that 1 oz. setts spaced 7.5" apart and 2 oz. setts spaced 15" apart were the most economic rates of planting. Under normal soil and climatic conditions of the hills of Himachal Pradesh, as stated by Patil (1961), the most economic returns from Up-to-date variety could be obtained by planting 1 oz. seed in rows spaced 24" apart.

MATERIAL AND METHODS.

The investigations reported under this brochure were undertaken in the form of a field experiment in the plot No.8 (A Block) of the farm of the Division of Agronomy, during the Rabi season, 1963-64. This experiment covered an area of 0.2024 hectares. The topographical gradient was from North to South, with good drainage.

It is evident that before carrying out any experiment on a particular patch of land, the previous history of the land intended for experiment and the local prevailing climate must be known due to their direct bearing on the results of the experiment.

Previous history of the plot :-

The season-wise cropping pattern of the plot since last 3 years is as follows :-

	Kharif.		Rabi.
1961-62 -	Students demonstration plots.		
1962-63 -	Cowpea	--	Tobacco.
1963-64 -	Maize	--	Potato.

Climate :-

Bhubaneswar is situated about 40 miles west of Bay of Bengal. Its altitude is 25.5 meters above the mean sea-level. Geographically, it is located at 20^{o}-15' (N) latitude and 85^{o}-52' (E) longitude. The mean annual precipitation approximates to 1646.43 mm. of which 1216.04 mm.

Table 1. **Bhubaneswar, Orissa.**

Meteorological Data, (November, 1963 to February, 1964).

Month.	Mean maximum temperature in C°		Mean minimum temperature in C°		Relative humidity, 7 A.M.		Relative humidity, 1 P.M.		Rain fall in mm.		No. of rainy days.	
	Current.	D.N.**	Current.	D.N.**	Current.	D.N.**	Current.	D.N.**	Current.	D.N.**	Current.	D.N.**
November	31.20	+2.93	1920	+2.97	95.10	+6.06	45.90	- 3.77	T*	-56.75	1	- 1
	(28.27)	-	(16.23)	-	(89.04)	-	(49.67)	-	(56.75)	-	(2.50)	-
December December	27.40	+0.32	14.40	- 0.26	91.80	+3.80	41.40	+ 2.73	0	- 2.16	0	-2.16
	(27.08)	-	(14.66)	-	(88.00)	-	(38.67)	-	(2.16)	-	(2 .16)	-
January	29.20	+2.94	16.60	+5.62	93.00	+1.28	45.00	+12.36	0	-16.66	0	-2.00
	(26.26)	-	(10.98)	-	(91.72)	-	(32.64)	-	(16.66)	-	(2.00)	-
February	30.70	-2.78	19.30	+2.35	92.00	+1.30	46.00	+17.00	24.80	-24.05	8.00	+3.00
	(33.48)	-	(16.95)	-	(90.70)	-	(29.00)	-	(48.85)	-	(5.00)	-

The figures in bracket indicate the normal average of 5 years.

* T - Traces.

** D.N. - Deviation from normal.

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	Current.	D.N. **	Current.	D.N. **	Current.	D.N. **	Current.	D.N. **	Current.	D.N. **	Current.	D.N. **
November	31.20 (28.27)	+2.93 -	1920 (16.23)	+2.97 -	95.10 (89.04)	+6.06 -	45.90 (49.67)	- 3.77 -	T* (56.75)	-56.75 -	1 (2.50)	- 1 -
December	27.40 (27.08)	+0.32 -	14.40 (14.66)	- 0.26 -	91.80 (88.00)	+3.80 -	41.40 (38.67)	+ 2.73 -	0 (2.16)	- 2.16 -	0 (2 .16)	-2.16 -
January	29.20 (26.28)	+2.94 -	16.60 (10.98)	+5.62 -	93.00 (91.72)	+1.28 -	45.00 (32.64)	+12.36 -	0 (16.66)	-16.66 -	0 (2.00)	-2.00 -
February	30.70 (33.48)	-2.78 -	19.30 (16.95)	+2.35 -	92.00 (90.70)	+1.30 -	46.00 (29.00)	+17.00 -	24.80 (48.85)	-24.05 -	8.00 (5.00)	+3.00 -

The figures in bracket indicate the normal average of 5 years.

* T - Traces.

** D.N. - Deviation from normal.

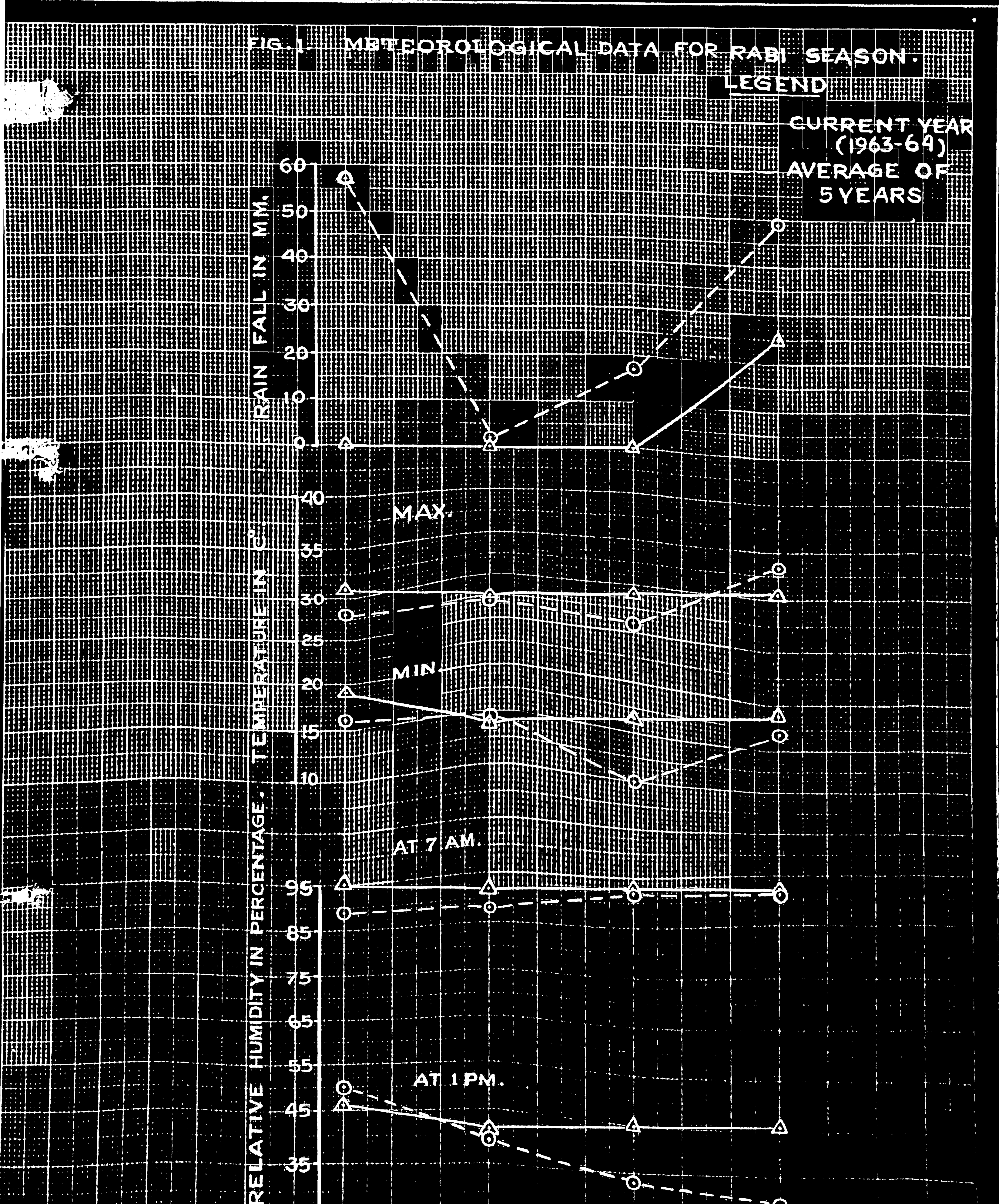
FIG. 1 METEOROLOGICAL DATA FOR RABI SEASON.
LEGEND
CURRENT YEAR (1963-64)
AVERAGE OF 5 YEARS
RAIN FALL IN MM.
60
50
40
30
20
10
0
TEMPERATURE IN C°.
40
35
30
25
20
15
10
MAX.
MIN.
RELATIVE HUMIDITY IN PERCENTAGE.
95
85
75
65
55
45
35
25
AT 7 AM.
AT 1 PM.
NOV.
DEC.
JAN.
FEB.

are received from June to September and 430.39 mm. from October to May. Mean maximum temperature during the hottest part of May and June varies from 35°C to 39°C and the mean minimum temperature in the coldest month of January varies from 13°C to 15°C. Rainfall during the growth period of the crop (from 12.11.63 to 24.2.64) is 24.80 mm.

The data on the weather conditions are obtained from the meteorological observatory of the Agronomy Division of Utkal Krushi Mahavidyalaya, Bhubaneswar. The weather conditions for the whole period of the experiment from November 1963 to February 1964 together with deviations from the normal weather conditions were calculated for the last 5 years. These calculated data incorporated in table I and Fig.I manifests the prevailing conditions of temperature, rainfall and humidity during the season under study.

M A T E R I A L.

(a) The soil :

The soil type of the experimental plot is loamy sand and well drained. Soon after layout of this experiment and immediately before application of any basal dressing of fertilizer, the soil samples by the help of a soil auger, to a depth of 15 cm. from the surface from randomly selected spots spread over the experimental plots from both the replications were taken. A representative composite sample was taken for both mechanical and chemical analysis. Similarly also a composite sample of soil was taken for the chemical analysis at post-harvest stage. The analytical

The following methods were used for the chemical analysis of the soil samples.

1. Total N was estimated by Kjeldahl method.
2. Available P was estimated by Bray's method.
3. Available K was estimated by Bray's method.
4. Organic C by Graham's method.
5. pH by Beckman's electronic pH. meter.

From the above table it is found that the soil of the experimental plot is poor with respect to K and P status is moderate. It is acidic in nature. All the nutrients supplied to the crop have not been utilised and hence the post-harvest analysis of the sample shows the presence of more of the nutrients than that of the soil sample taken before the start of the experiment. It was also found that the acidity of the soils slightly increased during the cropping period.

(b) The variety :

The variety used in the experiment was Red Patna which is synonymous to Darjeeling Red Round which is an old indegenous variety probably introduced into India from Europe during as early as seventeenth century and is , since then, extensively cultivated in plains. It is a late maturing and high-yielding variety in plains but keeping quality is good in hills. Its cooking qualities are : - cooks on prolonged boiling, easy to peel, flesh yellow, waxy texture, flavour strong, and pleasant taste. It does not stand water-logging conditions, particularly in figures are presented in the tables 2(a) and 2(b).

Table 2(a) - Showing mechanical analysis of surface soil (15 cm).

Particulars.		Percentage of composition.
Coarse sand	-	53.95
Fine sand	-	28.85
Silt	-	9.40
Clay	-	9.78
Textural class	-	Loamy sand.

Table 2(b) - Showing the chemical composition of surface soil (15 cm.).

	Pre-sowing.	Post-harvest.
Particulars.	Amount.	Amount.
Total N	0.081 %	0.093 %
Available P	288.40 Kg./ha.	343.00 Kg./ha.
Available K	97.44 Kg./ha.	115.36 Kg./ha.
Organic C	0.625 %	1.075 %
C : N ratio	7.716	11.559
pH	4.5	4.4

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Size in suth (local)	Diameter in mm.	Weight in gms.
4 (small)	upto 13	2.451
6 (medium)	13 - 19	7.407
8 (large)	19 - 25	12.820

(c) Fertilizer used :

Calcium ammonium nitrate, single super phosphate and muriate of Potash to supply N, P_2O_5 and K_2O respectively were used.

(d) Miscellaneous :

For the primary cultivation the mould board plough was used for first and the second ploughing and for the subsequent ones the Desi ploughs were used. Hand tools like Phaurah, hoe with long handle and spades were used for inter-culture. Bamboo pegs, lables, meter scale, dial micrometer and plannimeters were used for singling out the plants and taking observations.

PLAN OF LAY-OUT.

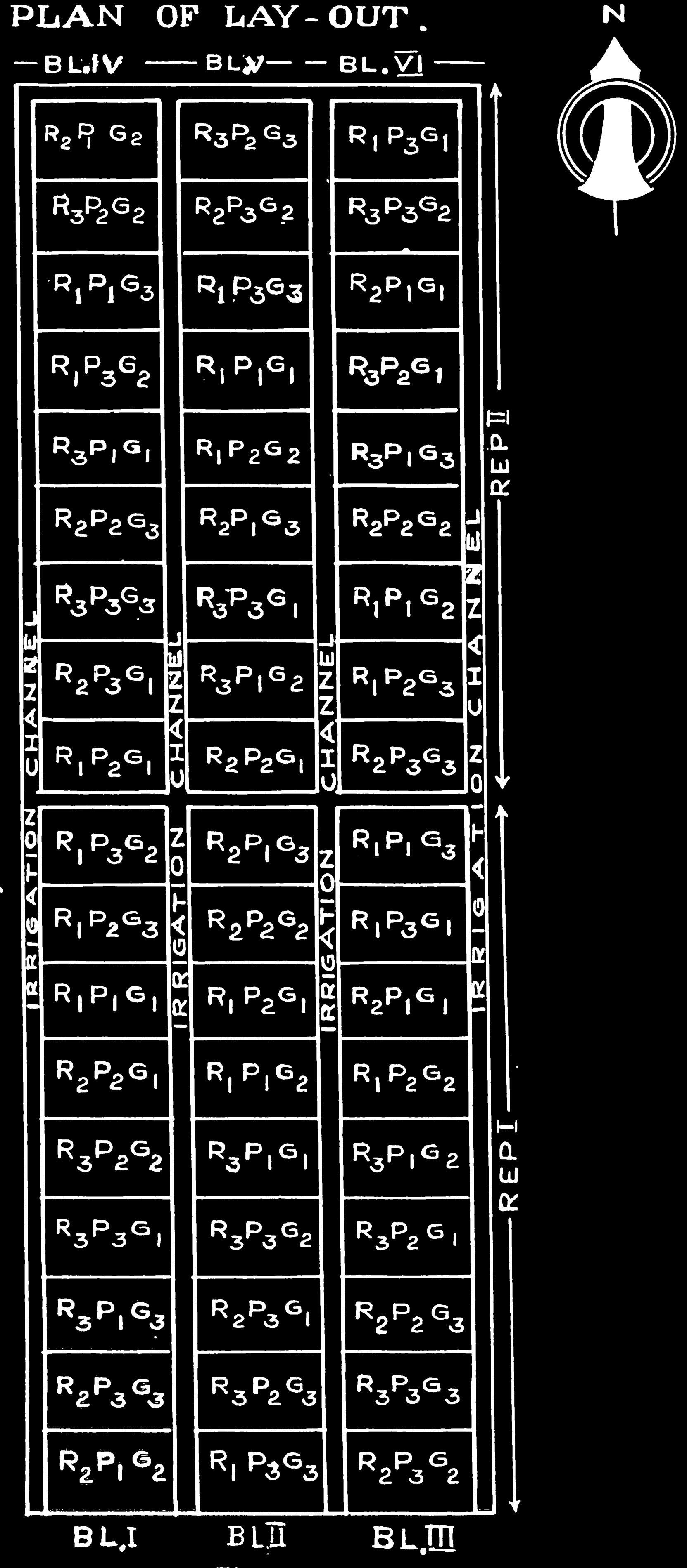


FIG. 2.

M E T H O D.

(a) Experimental technique:

The experiment was designed to study the effect of spacing and seed tuber grades on the yield and size of potato. The plan of lay-out is given in Fig.2. The details of the experimental technique are given below.

(1) Design:

The experiment was carried out in a 3^3 confounded factorial design replicated twice with 3 blocks of 9 plots each in a total area of 0.2024 hectares. The effect of RP^2G^2(W) and RP^2G (X) are confounded.

(2) Treatments :

There There were 3 treatments of 3 levels each making a total of 27 treatment combinations. R is the row spacing P is the Plant spacing in the row and G represents the tuber size. The details are given below.

I. Spacing (i) Row to row (R)

R_1 - 40 cm.
R_2 - 60 cm.
R_3 - 80 cm.

(ii) Plant to Plant (P)

P_1 - 15 cm.
P_2 - 20 cm.
P_3 - 25 cm.

II. Seed tuber grades (G)

G_1 - 4 suth.
G_2 - 6 suth.
G_3 - 8 suth.

(3) Plot size :

(i) Gross plot size - 4.8 m. x 6 m. or 28.8 Sq.m. or $\frac{1}{347.2222}$ ha. or 0.0029 ha.

(ii) Net plot size - There are 9 different net plots due to 9 spacing combinations as per the details given below.

Sl. No.	Particulars.	Spacing.	Area.	Hectare factors.
1.	$R_1 P_1$	- 4.0m. x 5.7m.	22.80 sq.m.	438.5964
2.	$R_1 P_2$	- 4.0m. x 5.6m.	22.40 sq.m.	446.4286
3.	$R_1 P_3$	- 4.0m. x 5.5m.	22.00 sq.m.	454.5455
4.	$R_2 P_1$	- 3.6m. x 5.7m.	20.52 sq.m.	487.3294
5.	$R_2 P_2$	- 3.6m. x 5.6m.	20.16 sq.m.	496.0317
6.	$R_2 P_3$	- 3.6m. x 5.5m.	19.80 sq.m.	505.0505
7.	$R_3 P_1$	- 3.2m. x 5.7m.	18.24 sq.m.	548.2456
8.	$R_3 P_2$	- 2.2m. x 5.6m.	17.92 sq.m.	558.0357
9.	$R_3 P_3$	- 3.2m. x 5.5m.	17.60 sq.m.	568.1818

(4) Area under experiment :

Total area - 92.m. x 22.m. or 2024 sq.m.

or 0.2024 ha.

(5) Technique followed in selecting sample plants :

Number of plants i.e. plant population in different plots varied due to the different spacings. So the constant number of plants was not selected for the purpose of taking observations though a constant area of 3.6 sq.m. with different plant population was selected and divided into 3 samples with 3 rows. The rows were selected by using one-digit Tippet numbers keeping aside 2 rows on either sides to eliminate the border effects. Likewise one plant in each row was selected by using two-digit randoms numbers leaving 2 lines on both sides. Starting from this particular plant the number of plants in a sample which is one-third of the whole sample taken for observations were counted for all observations from S-W direction. The pegs were fixed on either side of the sample plants only for comparing the yield of tubers. But for studying other Agronomic plant characters 10 plants from the sample with 3 plants from 1st sample row, 4 from 2nd sample row and 3 from 3rd sample row were taken in each plot. In each sample row the two extreme plants and the middle most ones were selected with exception of the 2nd sample row where in-stead of the middlemost plant, 2 adjacent middle plants were taken. Each sub-sample plant was marked with lable. The number of sample plants with total and net population for different spacing combinations is given below

Spacing combinations.	Total No. of plants in gross plot.	No. of plants in net plot.	No. of sample plants.
R_1P_1	480	330	20 x 3 = 60
R_1P_2	360	280	15 x 3 = 45
R_1P_3	288	220	12 x 3 = 36
R_2P_1	320	228	13 x 3 = 39
R_2P_2	240	168	10 x 3 = 30
R_2P_3	192	132	8 x 3 = 24
R_3P_1	240	152	10 x 3 = 30
R_3P_2	180	112	8 x 3 = 24
R_3P_3	144	88	6 x 3 = 18

(6) Statistical analysis :

All the data concerning the yield and the biometric observations were analysed statistically. The effects of RPG and RPG^2 were found out from both replications and each of the effects of RP^2 G^2 and RP^2 G were obtained from replication I and replication II respectively. The analysis of variance table was prepared. The treatment effects were tested by 'F' test. The Standard Error of means and critical differences at 5% level were calculated by the following formulae

$$S.E.(m) = \sqrt{\frac{E.M.S.}{18}} \quad \text{(for main factors)}$$

$$\text{and} \quad \sqrt{\frac{E.M.S.}{6}} \quad \text{(for treatment combination)}$$

$$C.D.(0.05) = S.E.(m) \times \sqrt{2} \times t \text{ at 22 df. at 5\% level.}$$

The graphs wherever found necessary were drawn by utilising the mean figures of observed data.

(b) Field technique :

(i) Preparatory cultivation -

The field was ploughed and cross ploughed by the mould board plough and two subsequent ploughings were done by Desi plough. Thorough laddering was done both breaking the clods and for levelling. The ploughing and laddering were done on the 5th and 6 th November1963. After the thorough preparation, the plot was laid out according to the plan on the 7th and 8th November 1963.

(ii) Seed and sowing :

Just before planting the healthy seed tubers of Red Patna variety, were treated for 1 minute with 0.5 % aretan solution. The tubers were planted on 11th and 12th November, 1963.

Lines were marked and shallow grooves were dug out with hand hoes on the lines as per row-to-row distance and the basic fertilizers were applied uniformly in the grooves and mixed thoroughly. Then with the help of a rope the treated tubers were planted at various plant to plant space as per the treatments mentioned earlier. The seed rate per hectare for different grades of different spacing combinations is given below.

Treatment combinations.	Population ('000)	Seed rate in Kg./ha.		
		4 Suth (13 mm.)	6 Suth (14-19 mm.)	8 Suth (19-25 mm.)
R_1P_1	167	410	1237	2141
R_1P_2	125	308	926	1603
R_1P_3	100	245	741	1282
R_2P_1	112	275	830	1436
R_2P_2	84	206	623	1077
R_2P_3	67	165	497	860
R_3P_1	84	206	623	1077
R_3P_2	63	155	467	808
R_3P_3	50	123	371	641

(iii) Fertilizer application :

Manures and fertilisers were applied with different quantities and methods as detailed below :

Manures/Fertilizers.	Doses/ha. (in Kg.)	Quantities per plot. (in Kg.)	Methods of application.
F.Y.M.	9,000	26	Basal, at final land preparation.
N-P-K. fertilizers	80-160-80	C.A.N.-1.296 Super-3.240 Muriate of potash-0.432	Basal application of entire quantity of super and muriate of potash and half of C.A.N. and the rest of C.A.N. topdressed at first earthing.

(iv) Irrigation :

The schedule of irrigation during the entire growth period of the crop plant is given below :

Method of irrigation.	Frequency.	Dates.	Remarks.
Pot watering.	4	13.11.63 to 19.11.63	On alternate day.
Sprinkling by scoop.	3	21.11.63 24.11.63 27.11.63	
Flooding.	2	29.11.63 4.12.63	
Furrow irrigation.	7	11.12.63 to 27.1. 64	At ten days interval.

(v) Interculture :

The first earthing followed by hoeing was done on 8.12.63 and 9.12.63 and the second earthing on

26,12.63 and 27.12.63, one replication each day.

(vi) Plant protection measures :

As mentioned earlier, the healthy seed tubers were selected for planting and just before planting the tubers were dipped in 0.5 % "Aretan" solution for a minute only. Total spraying material of 330 litres containing 0.3 % of Blitox and 0.2 % of Taf ərin were sprayed the whole experimental area in order to prevent early blight and to control Epilachna beetle respectivelyt twice on 18.12.63 and 6.1.64.

(vii) Harvesting :

When the potato plants attained the complete dry stage, the crop was harvested. Border plants were dug-out on two consecutive days on 18th and 19th February 1964. So also the sample plants on 20.2.64 and 21.2.64, rest of the plots on 22.2.64 and 23.2.64. The fresh weight was recorded immediately after harvest.

OBSERVATION TECHNIQUE.

I. Pre-harvest observations -

All pre-harvest observations were recorded on five different dates at ten days interval starting from forty-five days after planting. unless otherwise specifically mentioned.

1) Germination -

The germination counts were taken thrice from 27.11.63 to 17.12.63 at 10 days interval. The percentage of germination was calculated for each sub-plot excluding the border plants. The first sprouting scattered here and there was noticed on 21.11.63.

2) <u>Observations recorded on sample plants</u> :.

i) Number of shoots per hill - Each hill having one seed potato gave rise to different numbers of shoots which were counted and the figures so obtained were averaged out.

ii) Average height of shoots per hill - The height of the main shoots of 10 hills were recorded in cms. from the base of the plants to the tip of the meristem. The average was calculated and after second earthing 5 cms. uniformly were added to this as the base plants were covered by the earthing which was found to be on an average 5 cms.

iii) Leaves per hill - The number of leaves of all shoots of each hill were counted and recorded on the five dates. The average was calculated.

iv) Stem girth - The stem girth at 7th internode was measured by dial micrometer and the figures were converted into centimeters as these were in inches.

v) Virus counts - The plants affected by virus (Rugose) were counted and recorded on 25.1.64 when it was expected to be maximum. The data were transformed into percentage values.

vi) Leaf area - When the growth was expected to be maximum, an observation was taken on leaf area by using plannimeter taking the 7th leaf only to account.

vii) Number of branches - One observation on the number of branches per hill was taken on 4.2.64 at the end of the vegetative growth.

II. Post-harvest observations :

All the sample plants which were within the pegs fixed and at the same time differing in number from plot to plot were harvested separately. The grading was done to represent 4 suth (13 mm.), 6 suth (14-19 mm.) and 8 suth (above 19 mm.).

Observations regarding root length, number and weight of tubers per sample and per hill gradewise, specific gravity of tubers and weight of dry haulm were taken.

Laboratory technique :

i) Soil analysis - The composite soil sample at pre-sowing and post-harvest were analysed chemically and N-P-K., pH, organic carbon were assessed on both the composite samples. Only mechanical soil analysis was done on presowing sample.

ii) Starch content in tubers - The starch content of tubers of composite sample for 3 grades was analysed by "Direct Acid hydrolysis method". The date are given below :

Grades.	Starch content.
Large	13.21 %
Medium	14.45 %
Small	8.79 %

iii) Specific gravity of tubers from sample plants - The tubers from different plots on equal weight basis were taken and washed thoroughly to remove soil, dirt etc. and to check soaking of water while taking the observation. Then the tubers were dipped in water in a measuring cylinder graduated to 1000 cc. The rise of water is equivalent to the volume of potato tubers of the particular sample. By dividing the weight of potatoes by its volume the specific gravity was determined.

EXPERIMENTAL FINDINGS.

During the period of investigations reported under this dissertation various plant characters as mentioned in the foregoing chapter have been recorded to assess the effect of different sizes of seed tubers, row and plant spacing, independently and in combinations. The results so obtained are presented in this chapter and are dealt under two sets of studies :

1. Growth and development studies.
2. Post-harvest studies.

The analysis of variance tables are given in appendix.

I. Growth and development studies :

1. Germination and final plant population :

Sound germination and good stand of the crop is a precursor of the ultimate maximization of out-turn of a crop. So the percentage of germination and final plant population were studied as presented in table 3 and Fig.3 and Fig.11 and the detailed description is given below

Seed tuber size - The treatment differences were significant with respect to size of the seed tubers. The large seed tubers gave significantly maximum percentage of germination of 84.69 % and medium and small seed tubers were in descending order giving 79.42 % and 77.68 % germination respectively. This trend and condition with respect to plant population was maintained throughout the study. But in the last study on germination percentage on the 35th day after planting large seed was significantly

Table 3.

Average percentage of germination at earlier growth stage and final plant population.

Treatments	Germination Days after transplanting 15	25	35	Final plant population 10 days before harvesting in transformed value.
R.levels.				
R_1	3.59	72.95	81.35	64.48(81. 4 %)
R_2	3.86	75.63	82.60	64.81(81. 9 %)
R_3	2.75	67.92	77.84	62.06(78. 0 %)
'F' test.	Sig.	Sig.	N.Sig.	N.Sig.
P.levels.				
P_1	3.28	68.77	77.79	62.15(78. 2 %)
P_2	3.29	73.35	81.98	64.91(82. 0 %)
P_3	3.61	74.38	82.02	64.29(81. 2 %)
'F' test.	N.Sig.	N.Sig.	N.Sig.	N.Sig.
G.levels.				
G_1	1.99	64.26	77.63	61.24(76. 9 %)
G2	3.43	73.42	79.42	63.14(79. 6 %)
G3	4.76	78.32	84.69	66.97(84. 7 %)
'F' test.	Sig.	Sig.	Sig.	Sig.
S.E(m)	±0.29	±2.04	±1.76	±1.20
C.D.(0.05)	0.85	5.98	5.16	3.53

superior to medium and small seed though the latter two did not differ much.

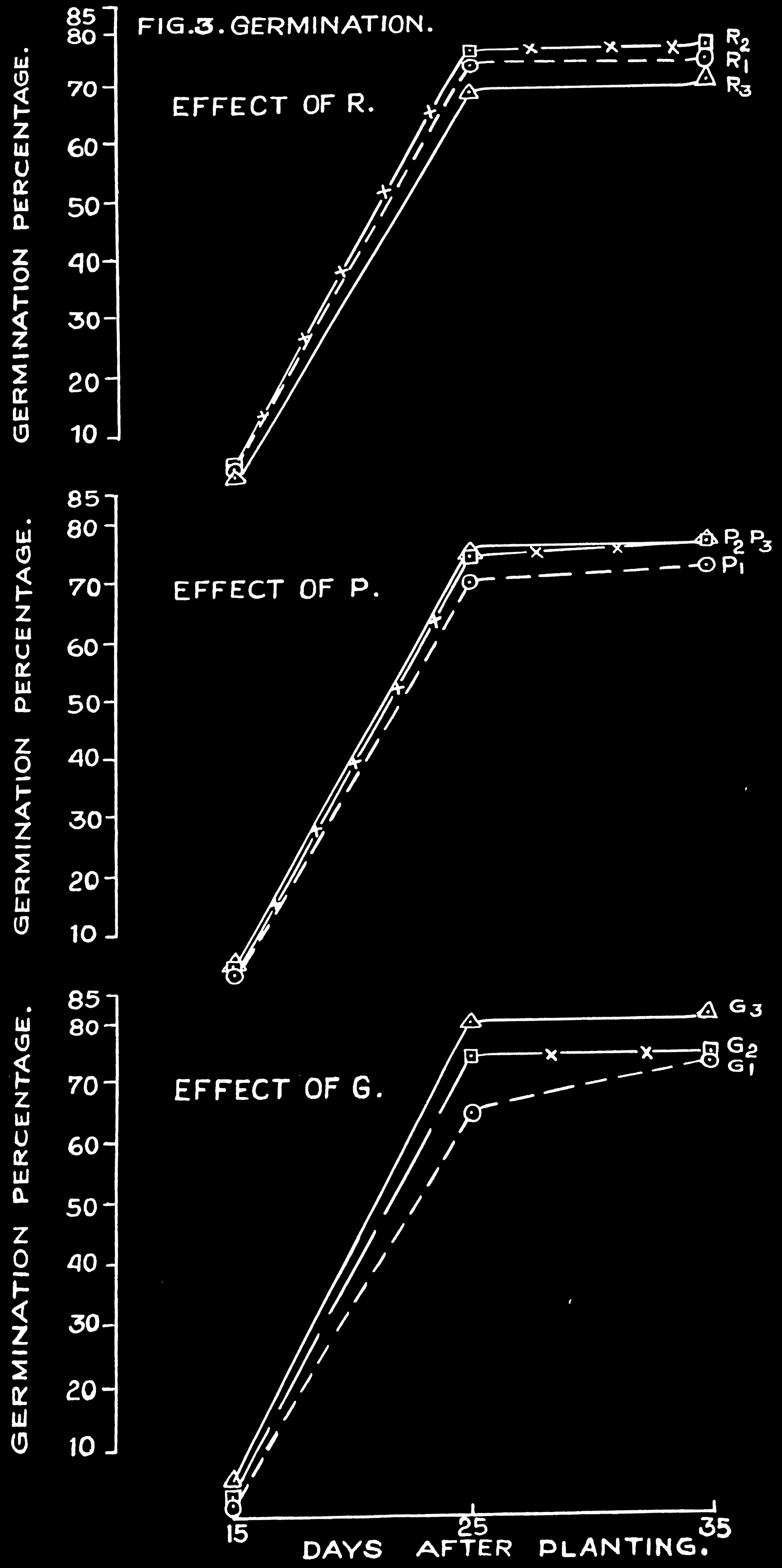


FIG.3. GERMINATION.
EFFECT OF R.
EFFECT OF P.
EFFECT OF G.
GERMINATION PERCENTAGE.
10
20
30
40
50
60
70
80
85
R2
R1
R3
P2 P3
P1
G3
G2
G1
15
25
35
DAYS AFTER PLANTING.

Row space - Regarding the row-spacing in the first stage 60 cm. gave the highest percentage of germination and was at par with 40 cm., both being significantly superior to 80 cm. In the second observation 60 cm. gave significantly maximum germination percentage and was at par with 40 cm. which did not differ significantly from 80 cm. The differences in the germination in the third and final plant population count were not significant but a trend similar to that obtained at second count was noticed in both the cases.

Plant space - No significant differences could be found in percentage of germination in all the observations recorded but increase in percentage of germination was observed with the increase in plant spacing in all the three dates of observations, though a slight deviation was the result in the final plant population study where 20 cm. gave the maximum plant population followed by 25 cm. and 15 cm. gave the minimum.

Interaction - There was no significant differences in germination and final plant population percentage due to the treatment combinations.

2. Number of shoots per hill.

The number of shoots is an important growth component which ultimately governs the yield of tubers.

The average data on number of shoots per hill calculated for the five observations recorded are presented in table 4 and graphically represented in Fig.4 and the statistical analysis reveals that the differences in

Table 4.

Average number of shoots in successive growth stage.

Treatments.	Days after planting 45	55	65	75	85
R.levels.					
R_1	2.04	2.17	2.17	2.09	1.61
R_2	2.05	2.09	2.11	2.06	1.63
R_3	2.04	2.09	2.09	2.07	1.70
'F' test.	N.Sig.	N.Sig.	N.Sig.	N.Sig	N.Sig.
P.levels.					
P_1	2.01	2.07	2.07	1.97	1.57
P_2	1.99	2.07	2.09	2.06	1.67
P_3	2.13	2.21	2.21	2.19	1.76
'F' test.	N.Sig.	N.Sig.	N.Sig.	Sig.	Sig.
G.levels.					
G_1	1.40	1.51	1.51	1.59	1.30
G_2	2.22	2.26	2.26	2.17	1.73
G_3	2.52	2.58	2.60	2.46	1.91
'F' test.	Sig.	Sig.	Sig.	Sig.	Sig.
S.E(m)	±0.074	±0.078	±0.077	±0.058	±0.045
C.D.(0.05)	0.217	0.229	0.226	0.170	0.132

Sig. - Significant. N.Sig. - Not significant.

number of shoots per hill due to the tuber grades planted were found to be significant all through the five stages of observations. There were no significant differences found in number of shoots due to either row-spacing or plant spacing except the later stages of growth where differences were significant due to plant spacing only.

Seed tuber size - The difference between the maximum and minimum number of shoots per hill due to size of seed tubers gradually showed a downward trend with the aging of the plants. It was also found that larger the size of the seed planted greater was the number of shoots per hill and the three different sizes, large, medium and small, gave the average number of shoots to the extent of 1.91, 1.73 and 1.30 respectively in the final observation.

Row space - As to the row spacing there were not much of differences noticed in the number of shoots per hill in all the observations.

Plant space - The numerical appraisal of the data showed that in the later growth stage from 75th day the plant spacing showed some significant difference. From the statistical analysis it was found that 25 cm. gave the maximum number of shoots and was at per with 20 cm. which did not differ from 15 cm.

Interaction - No significant differences were found throughout the growth except on 75th day after planting

AVERAGE
FIG.4. NO. SHOOTS / HILL.

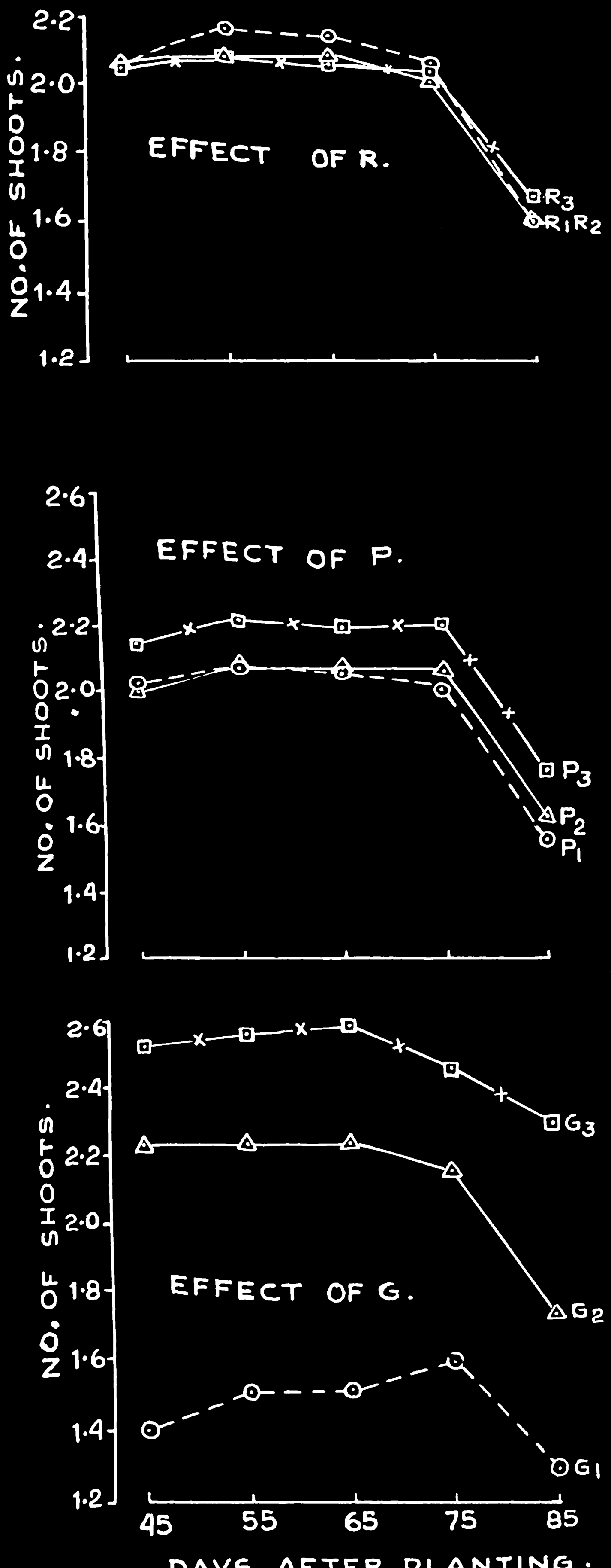
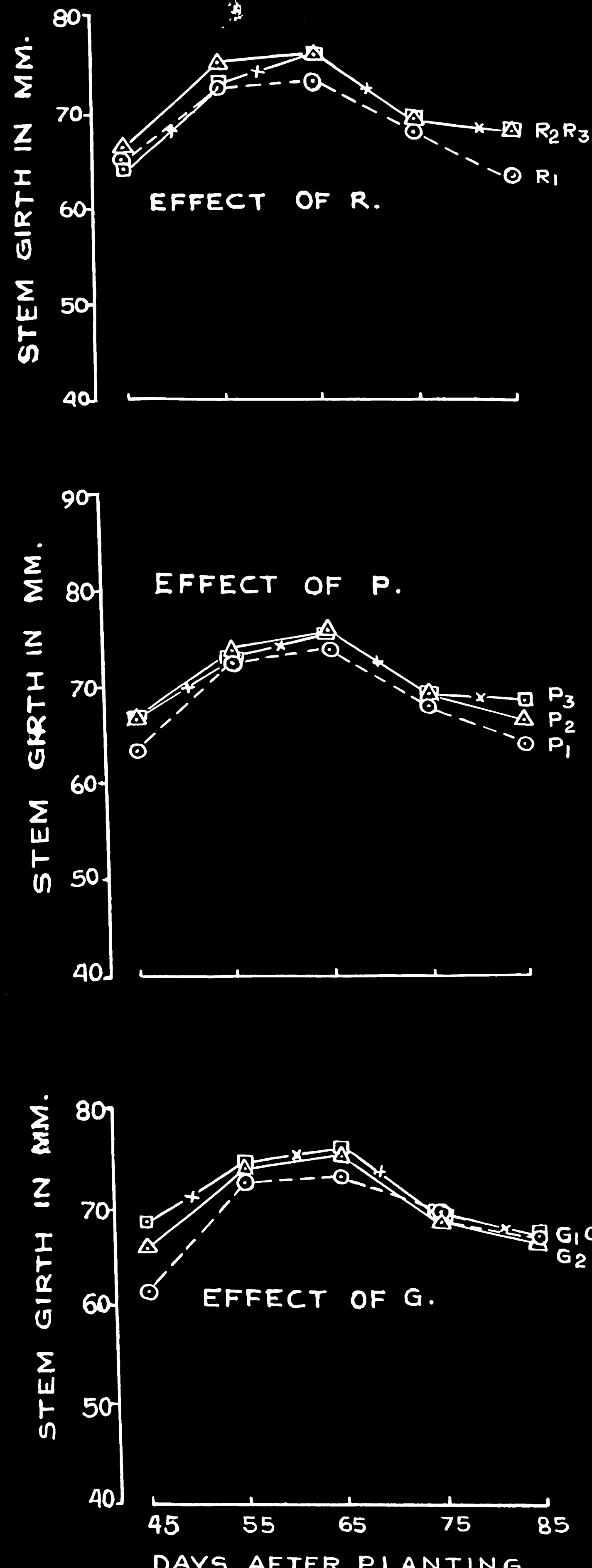


FIG.5. AVERAGE STEM GIRTH.



due to plant space and seed size combinations. From the

Table 4(a).

Average number of shoots per hill due to P X G interaction at 75 days after planting.

P.Levels.	G. levels		
	G_1	G_2	G_3
P_1	1.48	2.27	2.15
P_2	1.57	2.07	2.55
P_3	1.72	2.17	2.70

S.E(m) $\pm$0.101 C.D. (0.05) 0.296

table 4(a) it was seen that 25 cm. Plant space in conjunction with the large seed tubers gave maximum and the close plant space combined with small tubers gave minimum number of shoot per hill.

3. Height of the plant.

Height is an index of plant growth and hence its study is quite essential. Five height measurements have been recorded at 10 days interval and the average data after being statistically analysed have been presented in table 5 and Fig.7.

Seed tuber size - From the table it is evident that in the first observation the height was influenced by the size of seed tubers. Large tubers were at par with medium and both were significantly superior to small tubers.

When the plants were 55 days old, it was found that small tubers exceeded in growth to large ones but both were at par and significantly superior to small tubers.

Table 5.

Average height of plants in cm. in successive growth stage.

Treatments.	Days after planting.				
	45	55	65	75	85
R.levels.					
R_1	24.79	41.78	48.23	50.23	56.83
R_2	25.37	41.52	49.08	52.29	55.63
R_3	22.06	46.70	50.16	53.69	57.74
'F' test	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig.
P.levels.					
P_1	24.26	40.52	47.37	50.78	56.01
P_2	24.13	41.99	50.57	53.16	58.26
P_3	23.83	41.99	49.03	52.27	56.13
'F' test.	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig.
G.levels.					
G_1	19.24	35.91	46.22	49.71	55.51
G_2	25.48	43.12	50.76	52.94	56.32
G_3	27.50	44.97	50.49	53.56	58.57
'F' test.	Sig.	Sig.	Sig.	Sig.	N.Sig.
S.E (m)	±1.094	±0.844	±0.866	±1.005	±0.911
C.D.(0.05)	3.208	2.475	2.540	2.947	

The same trend in growth with respect to height was observed at third observations. After 75 days the difference in height were almost of the similar nature as that of

1. General view of the experimental plot at 65 days.

first observation. The height measurements were found not to differ much due to three grades of tubers planted at the last observations i.e. 85 days after planting.

Row space. For row spacing 30 cm., although inferior in early stages proved to be superior to 60 cm. and 40 cm. in the later stages but there was no significant differences in all the observations.

Plant space - As to the plant space it can be mentioned that 20 cm. gave the tallest plants though the differences in plant height due to different plant spaces were not significant.

Interaction - In all the observation no differences of the treatment combinations were found to be significant except in the third observation where the combinations

Table 5 (a).

Average height of plants in cm. at 65 days after planting due to P X G interaction.

P. levels.	G. levels.		
	G_1	G_2	G_3
P_1	1.47	2.38	2.35
P_2	1.50	2.13	2.62
P_3	1.55	2.27	2.82

S.E(m) 1.499 C.D.(0.05) 4.396

of plant space and seed size gave significant differences as found in table 5(a). Out of 9 such treatment combinations

FIG. 6. AVERAGE NO. OF LEAVES / HILL.

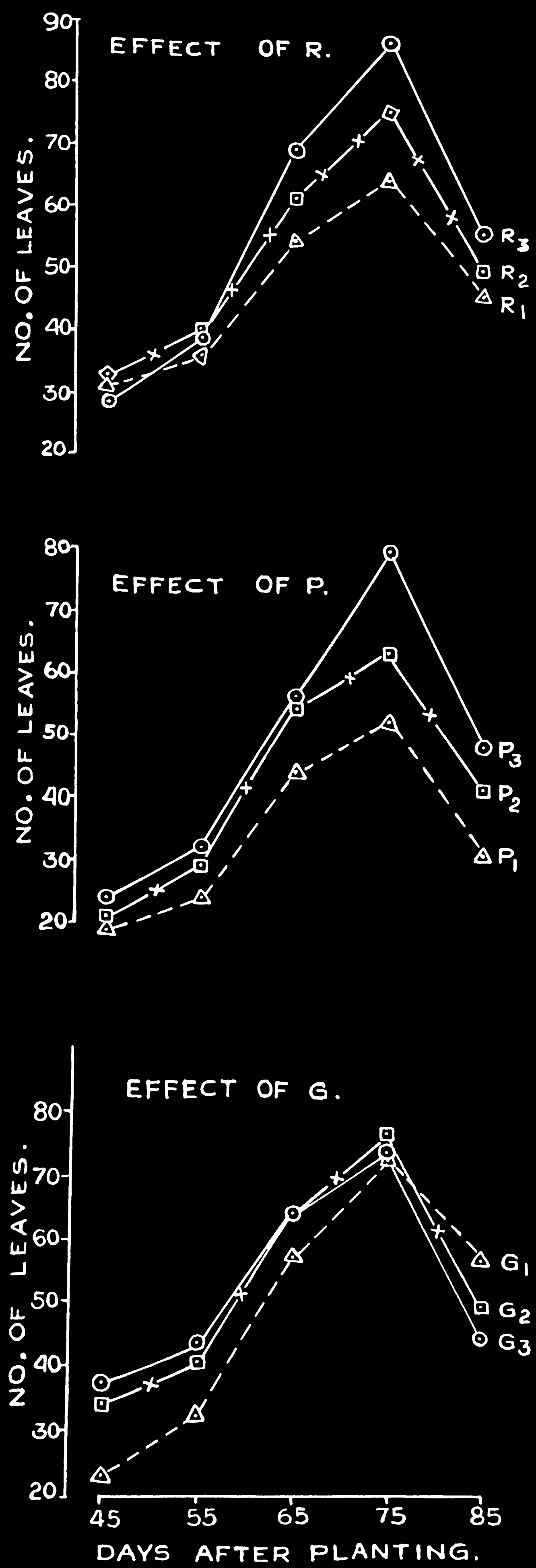
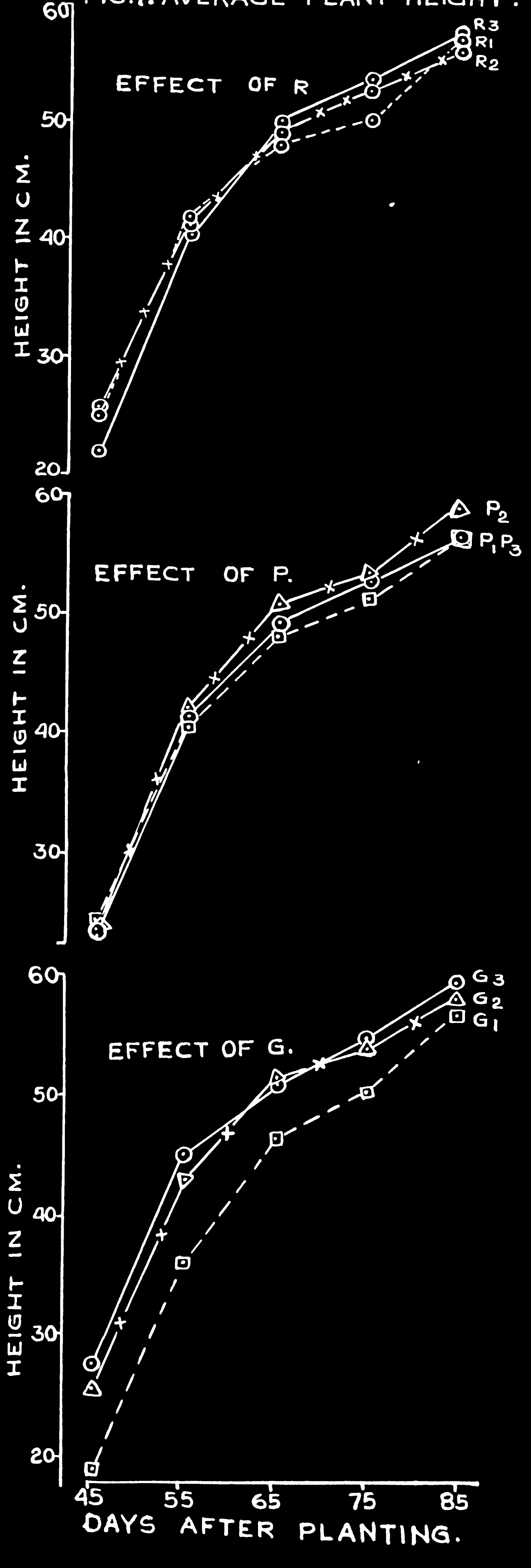


FIG. 7. AVERAGE PLANT HEIGHT.



15 cm. plant space combined with medium tubers produced the tallest plants (52.42 cm.) 25 cm. plant space in conjunction with small tubers were at par and inferior to the rest which were also at par.

4. <u>Number of leaves.</u>

The leaves in a plant life, in general play

Table 6.

Average number of leaves per hill in successive growth stage.

Treatments.	Days after planting. 45	55	65	75	85
R.levels.					
R_1	31.17	36.17	54.26	63.82	45.30
R_2	33.43	39.93	60.71	74.91	49.43
R_3	28.83	39.66	69.39	85.53	54.64
'F' test.	N.Sig	N.Sig	Sig.	Sig.	N.Sig.
P.levels.					
P_1	29.23	34.41	54.30	62.08	40.60
P_2	30.53	38.90	63.65	73.34	51.19
P_3	33.67	41.45	66.41	88.84	57.58
'F' test.	N.Sig.	Sig.	Sig.	Sig.	Sig.
G.levels.					
G_1	22.56	31.81	56.71	73.20	56.59
G_2	33.60	40.27	63.99	77.43	48.62
G_3	37.27	42.68	63.66	73.63	44.16
'F' test.	Sig.	.Sig.	.Sig	N.Sig.	N.Sig.
S.E (m)	±1.695	±[illegible].549	±1.657	±3.664	±3.635
C.D.(0.05)	4.971	4.543	4.860	10.745	10.660

an eminent role as they are the kitchen for manufacture of food which is so vital for living being. It is of special importance to the crop like potato where in addition to meet the food requirement of the plant for growth, a heavy amount of food is to be stored underground to supply food for human consumption. Therefore the study for differende aspects of leaf attracts attention of all engaged in scientic research.

With the above object in view five observations on number of leaves per hill were taken and the data so obtained were statistically analysed which reveals the following(table - 6 and Fig.6.)

Seed tuber size - In the first observation, 45 days after planting large and medium tubers were at par and both were significantly superior to small ones. In the second observation a similar trend was noticed as to the difference in number of leaves due to tuber grades. In the third observation, it was found that medium tubers gave the highest number of leaves but was at par with large tubers, both were statistically superior to small ones. In the later stage of growth there was no significant difference in leaf number due to tuber grades but in the last observation, it was observed that small seed tubers showed the tendency of producing maximum number of leaves.

Row space - From the date it was found that the differences in number of leaves indifferent treatments in first two observations were not sighificant. But 60 cm.

gave the maximum number of leaves in both the observations. In the third observation, 65 days after planting 80 cm. was found to be significantly superior to 60 cm. which in turn was significant over 40 cm. In the fourth observation, 75 days after planting the data revealed that 80 cm. gave maximum number of leaves and was at par with60 cm. and both were significantly superior to 40 cm. In the last observation the trend was like that of fourth one but the differences were not significant.

Plant space - Regarding plant spacing the data in the first observation revealed that 25 cm. gave maximum number of leaves followed by 20 cm. and 15 cm. without any significant differences but subsequently the differences were significant and 25 cm. Plant space continued to give maximum number of leaves all throughout. The number of leaves produced per hill was maximum at 75 days after planting after which the leaf number was reduced.

Interaction - The statistical data revealed that there were no significant differences inthe leaf number due to treatment combinations throughout the growth period.

5. <u>Leaf area</u>

It is not only the number of leaves per hill which counts for food synthesis in a plant but also it matters much as to how large they are . Keeping in view of this fact, the leaf area was recorded 82 days planting and the data were analysed statistically and presented in table 7 and Fig.9.

Table 7.

Average leaf area in sq.cm. at 82 days after planting.

Treatments.	Leaf area in sq.cm.	'F' test.	S.E(m)	C.D.(0.05)
R.levels.				
R_1	60.11			
R_2	60.03	N. Sig.		
R_3	54.00			
P.levels.				
P_1	54.91			
P_2	59.56	N. Sig.	= 3.99	
P_3	59.67			
G.levels.				
G_1	57.38			
G_2	59.63	N.Sig.		
G_3	57.13			

There were no significant differences in leaf area due to treatments. But the medium sized tubers were found to produce the largest leaves. The size of the leaves also increased as the rows were closer but a diagonally opposite trend was found due to plant spacing where larger leaves were produced as the tubers were planted wider.

No significant differences in leaf area were found due to treatment combinations.

6. <u>Stem girth</u>.

Thickness of the stem is one of the important vegetative characters which govern the yield of tubers. The average data on stem girth recorded on five different dates were statistically analysed.

Seed tuber size - As evident from the table 8 and Fig.5 the tuber grade affected the stem girth in the first observation i.e. after 45 days of planting. Large and medium tubers were at par and significantly superior to small ones. In the second as well as third observation there were no significant differences due to tuber grades but the trend was of the same nature as that of first one. In the 4th observation, 75 days after planting the trend was diagonally opposite where small tubers gave significantly more stem girth, was at par with medium ones. In turn medium tubers at par with large ones. The differences in stem girth due to grades were not significant in the last observation though large and small tubers were found to be superior to medium ones.

Row space - So far as the row spacing was concerned, no significant differences were found due to treatments in the first two observations. Here 60 cm. showed a tendency to behave better than 30 cm. and 40 cm.. In the third observation although the trend was same but the differences were significant. 60 cm. and 30 cm. were at par and both showed more stem girth than 40 cm. In the next observation a similar trend was noticed.

Table 8.

Average stem girth in mm. in successive growth stage.

Treatments.	Days after planting.				
	45	55	65	75	85
R.levels.					
R_1	6.54	7.26	7.33	6.78	6.36
R_2	6.66	7.53	7.61	6.96	6.73
R_3	6.46	7.30	7.59	6.94	6.31
'F' test.	N.Sig.	N.Sig.	Sig.	Sig.	N.Sig.
P. levels.					
P_1	6.36	7.28	7.41	6.83	6.41
P_2	6.64	7.42	7.58	6.92	6.63
P_3	6.66	7.39	7.54	6.93	6.36
'F' test.	N.Sig.	N.Sig.	N.Sig.	Sig.	N.Sig.
G.levels.					
G_1	6.16	7.24	7.39	6.92	6.68
G_2	6.63	7.39	7.51	[illegible].89	6.59
G_3	6.87	7.46	7.63	6.87	6.68
'F' test.	Sig.	N.Sih.	N.Sig.	Sig.	N.Sig.
S.E (m)	±0.12	±0.09	±0.07	±0.014	±0.15
C.D.(0.05)	0.35	-	0.21	0.04	0.15

In the final observation, no treatment differences were found to be significant.

Plant space - As regards the plant spacing no significant differencesdue to treatment were found at the initial growth stage. In the last two observations it was noticed that 25 cm. was apparently superior to 20 cm. and both were significantly superior to 15 cm.

Introduction - The average data on stem girth as available from the statistical analysis presented in table 8(a), 8(b) and 8(c) it was found that the three

Table 8(a).

Average stem girth in mm. due to R X P interaction at 75 days after planting.

P.Levels.	R.levels R1	R2	R3
P_1	6.66	6.98	6.86
P_2	6.76	7.02	6.97
P_3	6.93	6.88	6.97

S.E(m) - 0.02 C.D.(0.05) - 0.06

Table 8(b).

Average stem girth in mm. due to R X G interaction at 75 days after planting.

G.Levels.	R.levels. R1	R2	R3
G_1	6.87	6.95	6.94
G_2	6.86	6.91	6.98
G_3	6.71	7.02	6.88

S.E(m) - 0.02 C.D.(0.05) - 0.06

factors i.e. R, P, and G in addition to behaving ... -

independently significantly superior were also found to influence the stem girth significantly in their

Table 8(c).

Average stem girth in mm. due to P X G interaction at 75 days after planting.

G.Levels.	P.levels. P_1	P_2	P_3
G_1	6.82	6.97	6.97
G_2	6.77	6.87	7.01
G_3	6.91	6.91	6.80

S.E(m) - 0.02 C.D.(0.05) - 0.06

all possible combinations at the 4th stage of observation i.e. 75 days after planting.

7. Number of branches per hill -

Plant growth is a combined effect of increase in the plant parts both aerial and under-ground. The effect of growth is reflected upon the ultimate yield of a crop plant. The yield of potato cannot be pushed up by plants unbranched but by plants having number of branches which is an index of better growth. With this conception in view, in the last stage of growth period the counts on " Number of branches per hill " were recorded and data obtained were statistically analysed and presented in table 9 and Fig.8.

From the table it is noticed that the differences in number of branches per hill were significant due to tuber size and row spacing. Plant spacing did not show any effect on the number of branches.

Table 9.

Average number of branches per hill.

Treatments.	Number of branches.	'F' test.	S.E(m)	C.D(0.05)
R.levels.				
R_1	7.76			
R_2	9.06	Sig.		
R_3	9.90			
P.levels.				
P_1	7.97			
P_2	9.56	N.Sig.	±0.55	1.63
P_3	9.19			
G.levels.				
G_1	10.29			
G_2	8.27	Sig.		
G_3	8.16			

Regarding tuber size the small tubers proved to be significantly superior to medium and large tubers where the latter two were at par.

80 cm. row space gave significantly maximum number of branches when compared with 40 cm. and the number of branches per hill were about 10 and 8 respectively.

There were no significant differences in number of branches due to the treatment combinations.

FIG. 8. NO. OF BRANCHES PER HILL.

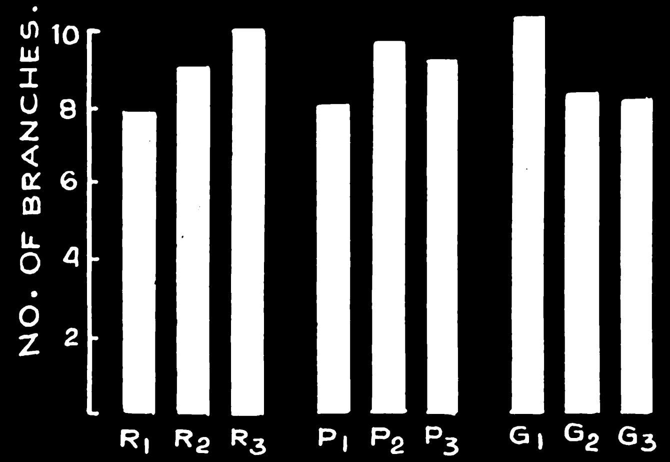


FIG. 9. LEAF AREA 82 DAYS AFTER PLANTING.

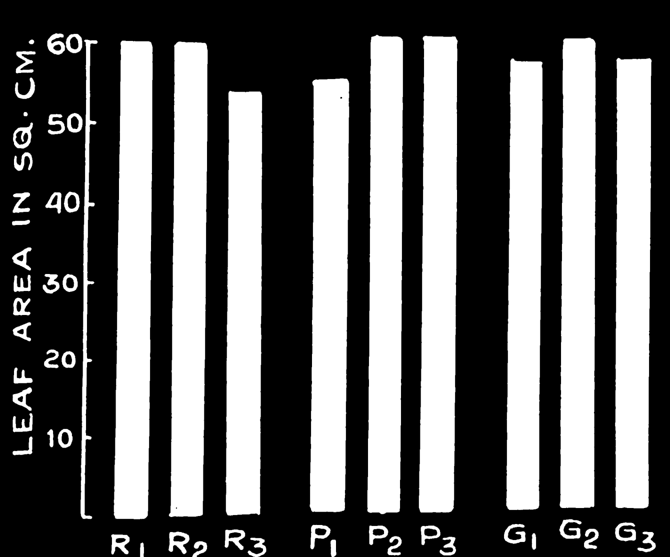


FIG:-10. PERCENTAGE OF VIRUS-AFFECTED PLANTS.

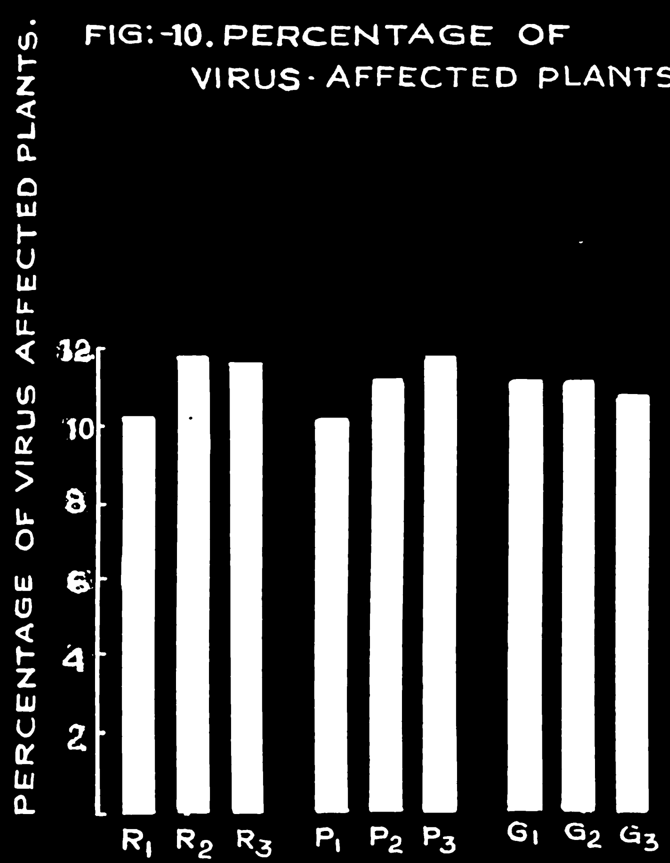
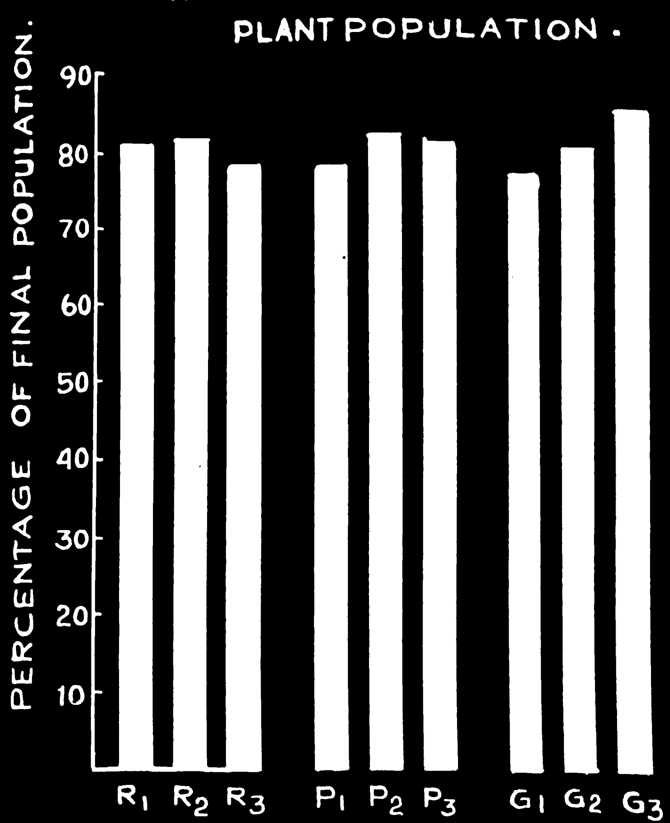


FIG. 11. PERCENTAGE OF FINAL PLANT POPULATION.



8. Percentage of virus-affected plants -

It is but natural to plant afresh seed material always from the original stock available from hills to avoid loss in yield caused by different viru. which is so fatal to potato. All the same it is of importance to see that the crop is free of virus infection

Table 10.

Average transformed values of virus affected plants.

Treatments.	Transformed values.	'F' test	S.E(m)	C.D.(0.05)
R.levels.				
R_1	3.208(10.29)			
R_2	3.421(11.70)	Sig.		
R_3	3.366(11.33)			
P.levels.				
P_1	3.208(10.29)			
P_2	3.358(11.28)	Sig.	±0.146	0.431
P_3	3.429(11.76)			
G.levels.				
G_1	3.357(11.27)			
G_2	3.357(11.27)	N.Sig.		
G_3	3.231(10.76)			

(Figures in bracket indicate the mean percentage.)

and is a healthy one all throughout its growing period. To have an idea of virus incidence, if any, noticed in the plants in the experiment under report, the number of plants affected by virus, expecially by rugose type was recorded plotwise and the average data obtained were statistically analysed and presented in table 10 and Fig.10.

As found from the table the differences in the incidence of virus in plants due to tuber size, were not significant though the significant differences were found due to row and plant spacings. Small tubers were more affected than large tubers and the percentage of infection on an average due to small tubers was 11.2% as against 10.76% of plants affected by large tubers. The percentage of affected plants was found to be maximum in case of 60 cm. row space which was at par with 80 cm. and both manifested significantly more percentage of affected plants than 40 cm. row space. Plant space of 25 cm. exhibited more percentage of affected plants and was at par with 20 cm. and both gave significantly more percentage of affected plants than 15 cm. It was noticed that when the spacing was close the percentage of virus affected plants was less.

Interaction - Table 10(a), 10(b) -

The differences of two sets of treatment combinations, R X P and R X G were found to be significant. In the first set of combination it was found that

R_1P_3 caused the highest percentage of virus incidence where R_1P_2 did the least. In the second set 30 cm. row

Table 10(a).

Average transformed values of virus affected plants due to R X P interaction.

P. levels.	R. levels. R_1	R_2	R_3
P_1	2.694 (7.26)	3.482 (12.12)	3.447 (11.88)
P_2	3.302 (10.90)	3.457 (11.95)	3.315 (10.99)
P_3	3.627 (13.15)	3.325 (11.05)	3.334 (11.11)

S.E(m) = 0.080 C.D.(0.05) 0.235

(Figures in bracket indicate the mean percentage)

Table 10(b).

Average transformed values of virus affected plants due to R X G interactions.

G. levels.	R. levels. R_1	R_2	R_3
G_1	3.424 (11. 72)	3.462 (11.98)	3.184 (10.14)
G_2	3.229 (10.43)	3.456 (11.94)	3.386 (11.46)
G_3	2.970 (8.82)	3.346 (11.19)	3.526 (12.43)

S.E(m) = 0.080 C.D.(0.05) 0.235

(Figures in bracket indicate the mean percentage)

space in combination with large tubers caused maximum percentage of infection but 40 cm. row space combined with large tubers did the minimum.

9. Root length.

The plants absorb the nutrients through their roots from different depth inside the soil. So intake of food from deeper sub-soil is more or less dependant upon the root length. With this view the maximum length of roots were measured and recorded.

Table 11.

Average root length in cm.

Treatments.	Average root length.	'F' test.	S.E(m)
R.levels.			
R_1	21.06		
R_2	20.81	N.Sig.	
R_3	20.59		
P.levels.			
P_1	21.66		
P_2	21.11	N.Sig.	± 0.55
P_3	20.14		
G.levels.			
G_1	20.24		
G_2	21.11	N.Sig.	
G_3	21.11		

The data obtained on the maximum length of root, were statistically analysed and the average maximum root length are presented in table 11 and plotted in Fig. 14.

The analysis reveals that the seed tuber size, plant or row space did not exert any effect on the maximum length of roots. However, there was a trend to increase in seed size. On the other hand with the planting of tubers wider, there was decrease in root length when row and plant spaces were considered.

There were no significant differences in maximum length of roots due to all possible combinations of the treatments.

10. Weight of dry haulm per hill.

Immediately before harvesting the crop the dry haulms were collected and their weight per hill was recorded and the data obtained were analysed statistically, (table 12, Fig.12). Significant differences in weight of dry haulms were found due to treatments as given below.

It was found that large tubers gave significantly more yield of dry haulm to the extent of 14.20 gm. per plant as compared to 10.79 gm. and 10.65 gm. yielded bymedium and small seed tubers respectively. In case of row spacing it was found that 80 cm. gave significantly more dry haulm than 60 cm. which also yielded significantly more than 40 cm. So far the plant spacing was concerned 25 cm. did not behave differently from

20 cm. and both gave significantly more dry haulm

Table 12.

Average weight of dry haulm in gm.

Treatments.	Average weight of dry haulm.	'F' test.	S.E.(m)	C.D.(0.05)
R.levels.				
R_1	8.26			
R_2	12.32	Sig.		
R_3	15.06			
P.levels.				
P_1	9.42			
P_2	13.11	Sig.	±0.61	1.79
P_3	13.11			
G.levels.				
G_1	10.65			
G_2	10.79	Sig.		
G_3	14.20			

per plant than 15 cm.

From the table 12(a) it can be seen that the

Table 12(b).

Average weight of dry haulm due to R x G interactions.

G.levels.	R.levels. R_1	R_2	R_3
G_1	8.80	11.47	11.68
G_2	8.40	10.18	13.78
G_3	7.57	15.30	19.70

S.E.(m) = 1.06 C.D.(0.05) 3.09

(FIG.12) WEIGHT OF DRY HAULM.

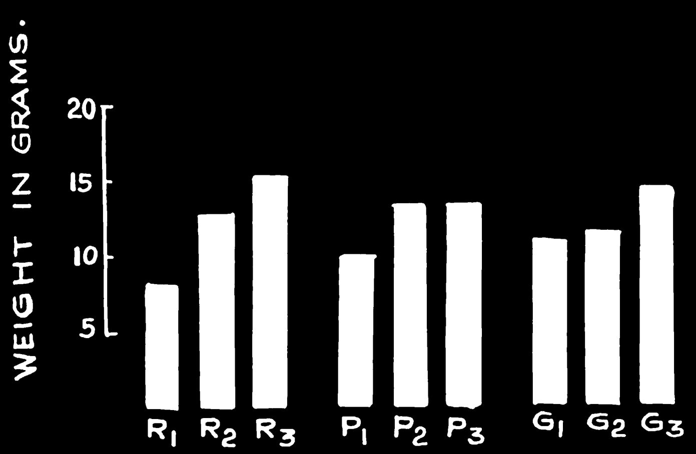


FIG.14. ROOT LENGH

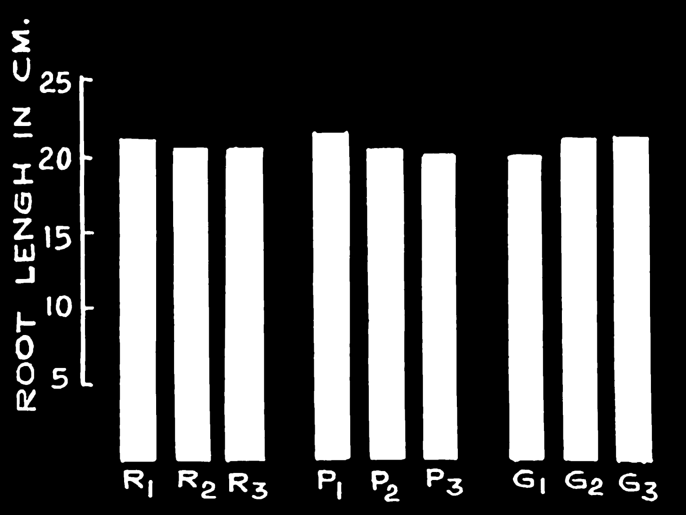


FIG.13. SPECIFIC GRAVITY OF TUBERS.

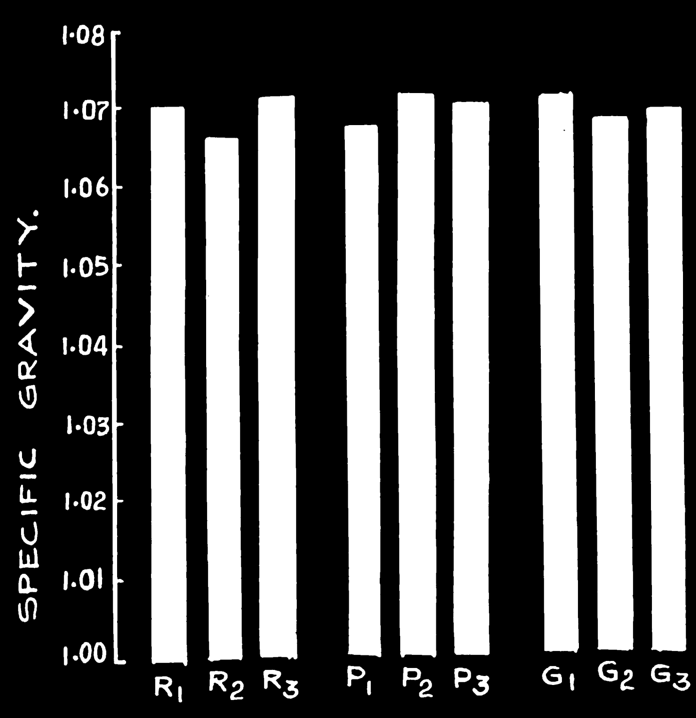
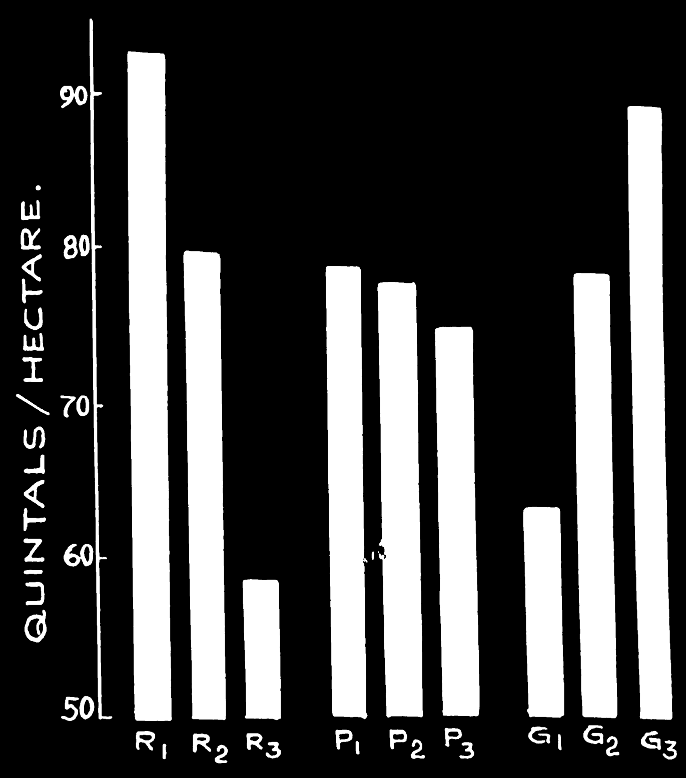


FIG.15. TOTAL YIELD OF POTATO.



differences due to interaction of row spacing and the size of tuber grades were significant. 80 cm. row space with large tubers was significant over all other combinations. 40 cm. row space with large tubers gave the minimum weight of dry haulms.

II. <u>Post-harvest studies</u> .

After the harvest of the crop total yield of tubers per hectare, number and weight of tubers produced per hill and per samples, the specific gravity of tubers were recorded and the data so obtained were statistically analysed and the results are given under this chapter.

1. <u>Total yield of tubers</u>.

Total yield of tubers are given in table 13 and graphically shown in Fig.15.

Seed tubers size - As regards the tuber grades it was found that the three grades - large, medium and small tubers gave tuber yields of the order of 89.45, 78.11 and 63.35 quintals per hectare respectively. The differences in yield were significant. Large sized tubers gave significantly higher yield than medium size which also significantly out-yielded small sized tubers.

Row space - From the statistical analysis it was found that the yield was influenced by the row spacing.

40 cm. spacing gave the highest yield to the tune of 92.72 quintals per hectare and was significantly superior to 60 cm. which also gave significantly higher yield of 79.52 quintals per hectare than 80 cm. space with 58.67 quintals per hectare of tuber yield.

Table 13.

Average yield of potato tubers in Quintals per hectare.

Treatments.	Yield of tubers.	'F' test.	S.E(m)	C.D.(0.05)
R.levels.				
R_1	92.72			
R_2	79.52	Sig.		
R_3	58.67			
P.levels.				
P_1	78.71			
P_2	77.49	N.Sig.	± 2.74	8.04
P_3	74.71			
G.levels.				
G_1	63.35			
G_2	78.11	Sig.		
G_3	89.45			

Plant space - From the statistical analysis it is seen that the planting of tubers in rows at the different spacings of 15 cm., 20 cm. and 25 cm. gave tuber yields of 78.71, 77.49 and 74.71 quintals per hectare respectively. The differences in yield were not significant.

Interaction - For the tuber yield point of view it was assessed that the different factors were independent of each other and they did not influence the yield in conjunction.

2. Grades of the tubers :

After harvesting the tubers were classified into 3 grades according to the diameter of the tubers. Large (more than 19 mm.), medium (14-19 mm.) and small (upto 13 mm.). The weight and number of tubers per sample (3.6 square meter) and per hill, were recorded and data obtained were analysed statistically and presented in table 14 and 15 and Fig.16 to 19.

Weight of tubers.

1) Grade - I (larger, ware)

Seed tuber size - Significant differences in weight of grade I tubers produced were found by planting different sizes of seeds, both for sample and hill basis. Large seed tubers produced grade I tubers of more weight than small ones.

Row space - On unit sample basis the differences in weight of grade I tubers produced due to row spacings were significant. Row spacings of 40 cm. and 60 cm. gave more weight of grade I tubers than

30 cm. but on basis of weight of tubers per yield 60 cm. and 30 cm. were superior to 40 cm.

Plant space - As regards the plant spacing though there was no significant differences due to treatments when calculated per sample basis, there was a regular trend of decrease in weight of Grade I tubers as the plant spacing increased from 15 cm. to 25 cm. But per hill basis, it was found that 25 cm. was significantly superior to 20 cm. and 15 cm. where the latter two were at par. It was noticed that the yield of Grade I tuber per sample was quite reverse in order when compared with that per hill.

Interaction - No interaction was significant as found from the statistical analysis of two sets of data on weight of grade I tubers per sample basis and per hill basis.

ii) <u>Grade II - (Medium or seed)</u>

From the statistical analysis it was found that the trend of increase in weight of grade II tuber yield was similar to that of grade I tubers. But in case of grade II tuber yield the difference due to treatments were not significant both in case of per sample and per hill bases except the row-spacing where significant differences were found on unit sample basis only.

Here in case of weight of grade II tubers per sample, 40 cm. was superior to the rest of the row spaces. But the yield of grade II tubers by weight per hill was more in case of 60 cm. followed by 30 cm. and 40 cm. without any signidicance in their differences.

Table 14.

Average weight of tubers.

Treatments	Per sample (in Kg.)			Per hill (in gm.)		
	Gr.I	Gr.II	Gr.III	Gr.I	Gr.II	Gr.III
R.levels.						
R_1	1.967	0.703	0.213	43.05	15.13	4.71
R_2	1.966	0.520	0.162	65.52	17.46	5.31
R_3	1.485	0.395	0.113	64.45	17.06	4.82
'F' test	Sig.	Sig.	Sig.	Sig.	N.Sig.	N.Sig.
P.levels.						
P_1	1.925	0.584	0.165	47.25	13.42	3.97
P_2	1.770	0.544	0.188	54.92	16.78	5.62
P_3	1.723	0.490	0.135	70.87	19.42	5.25
'F' test	N.Sig.	N.Sig.	N.Sig.	Sig.	N.Sig.	N.Sig.
G.levels.						
G_1	1.395	0.500	0.196	45.61	15.60	5.66
G_2	1.884	0.541	0.156	60.96	16.57	4.82
G_3	2.137	0.577	0.136	66.45	17.48	4.36
'F' test	Sig.	N.Sig.	N.Sig.	Sig.	N.Sig.	N.Sig.
S.E (m)	±0.130	±0.041	±0.017	±4.56	±1.32	±0.57
C.D.(0.05)	0.381	0.120	0.050	13.37	-	-

No interaction was significant except P X G combinations in case of sample basis as presented in Fig.14(a). 15 cm. plant spacing in combination with large tubers was superior to all other combinations.

Table 14(a).

Average weight of Grade II tubers in Kg. due to P X G combinations. in (sample basis)

G.levels.	P.levels. P_1	P_2	P_3
G_1	0.391	0.647	0.464
G_2	0.612	0.459	0.551
G_3	0.750	0.525	0.456

S.E (m) ± 0.071 C.D.(0.05) 0.203

15 cm. with small seed tubers gave minimum yield of grade II tuber weight.

iii) Grade III. (small or chat)

Seed tuber size - From the data it was seen that as the size of the seed tubers increased from G_1 to G_3, the yield of small sized (Grade III) tubers decreased. But in no case the differences were significant.

Row space - In case of row spacing 40 cm. produced significantly more small tubers, calculated on sample basis, followed by 60 cm. and 30 cm. where the latter two were at par. But when calculated per

FIG.16 NO. OF TUBERS PER SAMPLE (3·6 SQ. METERS)

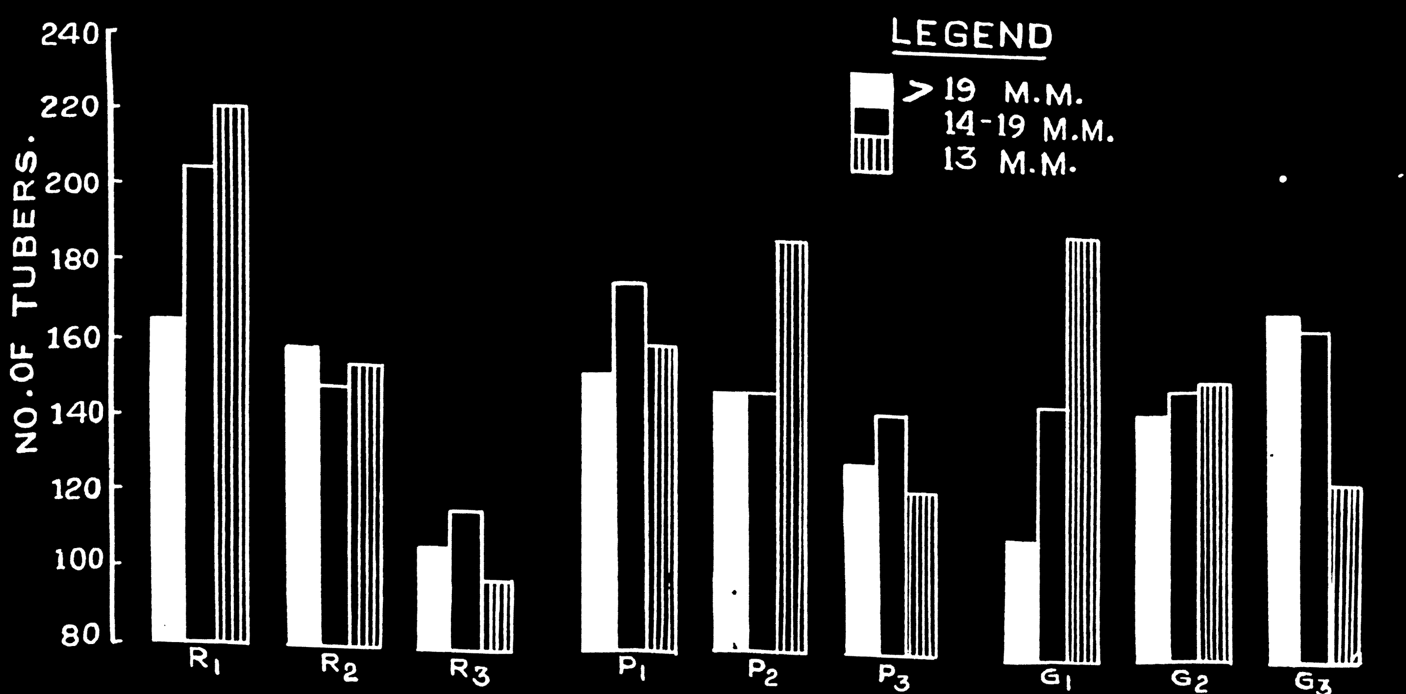
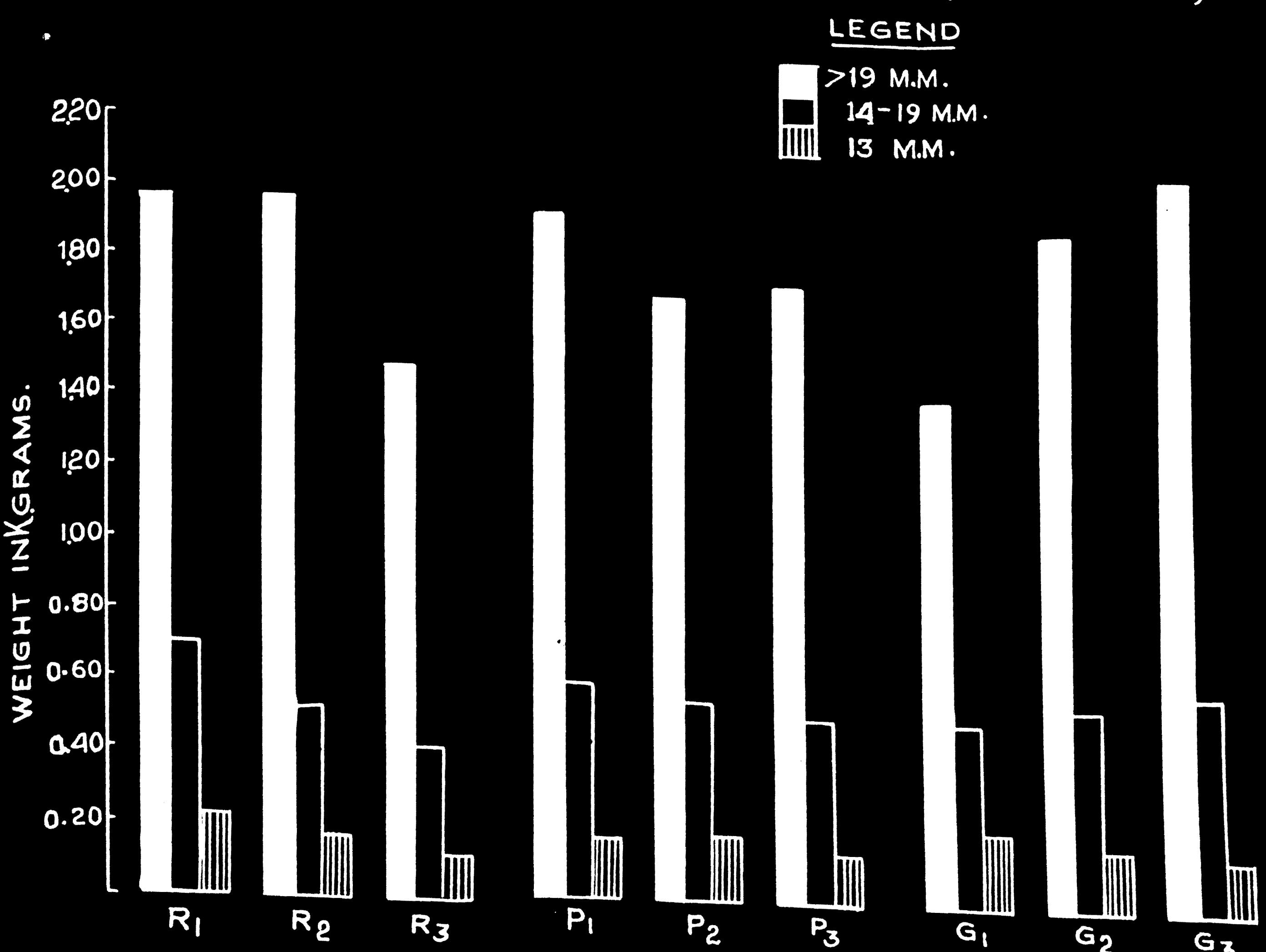


FIG.17. WEIGHT OF TUBERS PER SAMPLE (3·6 SQ. METERS.)



hill basis it was found that 60 cm. gave more yield than 40 cm. and 80 cm. without any significance in differences.

Plant space - As to the plant spacing data on small sized tubers on sample basis were analysed, it was found that 20 cm. was better than 15 cm. and 25 cm. In case of tubers per hill basis 20 cm. was better than 25 cm. and 15 cm.

Interaction - There were no significant differences due to the treatment combinations.

Number of tubers.

i) Grade I.

Seed tuber size - By analysing the data on number of grade I tubers on unit sample and per hill basis it was found that the larger the seed tuber more the number of large tubers produced. Large seed tubers gave more number of tubers than medium tubers but both were at par and significantly superior to small ones.

Row space - When the row spacing was analysed on sample basis, 40 cm. gave more number of grade I tubers than 60 cm. but both were at par and significantly, superior to 80 cm. But on hill basis 60 cm. proved to be the best in producing the number of grade I tubers but was at par with 80 cm. and both were significant over 40 cm.

Age constant, growth influenced by plant spacing.

Age constant, growth influenced by row spacing.

Age constant, growth influenced by tuber size.

3. Growth of potato [illegible]

[illegible] space - [illegible] analysed on single basis, [illegible] cm. gave [illegible] number of grade I

Table. 10.

Average number of tubers.

Treatments.	Per single Gr.I	Gr.II	Gr.III	Per hill Gr.I	Gr.II	Gr.III
[illegible] levels.						
R_1	16[illegible].72	[illegible].85	[illegible].56	5.54	4.37	4.83
R_2	157.[illegible]	14[illegible].11	155.8[illegible]	5.25	[illegible].94	5.01
R_3	1[illegible]	11[illegible]	95.61	4.61	4.9[illegible]	[illegible].19
'F' test	sig.	sig.	sig.	N.sig.	N.sig.	N.sig.
P levels.						
P_1	1[illegible]	170.72	10[illegible].7[illegible]	5.70	[illegible]	5.77
P_2	147.50	147.21	1[illegible]7.7[illegible]	[illegible]	4.57	[illegible]
P_3	1[illegible].17	1[illegible].01	1[illegible].11	[illegible]	[illegible].66	[illegible].76
'F' test	N.sig.	N.sig.	N.sig.	sig.	N.sig.	N.sig.
G.levels.						
G_1	111.[illegible]	147.6[illegible]	19[illegible]	5.56	4.5[illegible]	5.4[illegible]
G_2	1[illegible]	15[illegible]	1[illegible].11	[illegible].01	[illegible].07	[illegible].64
G_3	17[illegible]	[illegible]7.56	1[illegible]7.1[illegible]	[illegible]	5.59	[illegible].95
'F' test	sig.	N.sig.	N.sig.	sig.	N.sig.	N.sig.
S.E (m)	±9.42	±15.13	±[illegible]	±[illegible]	±[illegible].45	± [illegible].61
C.D.(0.05)	27.[illegible]	44.37	65.54	[illegible].94	-	-

tubers than 60 cm. but both were at par and significantly superior to 30 cm. But on hill basis 60 cm. proved to be the best in producing the number of grade I tubers but was at par with 45 cm. and both were significant over 4[illegible] cm.

Plant space - About the plant spacing for reducing the number of grade I tubers on single basis, no significance was found in the differences due to the treatments. However, the yield of number of grade I tubers remained as the [illegible] increased from 1[illegible] cm. to [illegible] cm. But the result on hill basis was just reverse where [illegible] cm. gave the maximum number of grade I tubers and was at par with [illegible] cm. and both were significantly superior to 15 cm.

Interaction - (Table 15([illegible])) From the analytical data on number of tubers per sample the differences due to P X G combinations were found

Table 15([illegible]).

Average number of Grade I tubers due to P X G combinations.

SAMPLE BASIS

G.levels.	P.levels. P1	P2	P3
G_1	1[illegible]	1[illegible]3.67	9[illegible]
G_2	1[illegible]	11[illegible]	1[illegible]
G_3	1[illegible].67	1[illegible]	1[illegible]

S.E(m) 16.31 C.D. (0.05) 47.83

significant. Out of the 9 treatment combinations, [illegible] cm. with large tubers produced the maximum and [illegible] cm. with small tubers the minimum number of grade I tubers.

ii) Grade II.

Seed tuber size - The number of grade II

FIG.18. NUMBER OF TUBERS PER HILL.

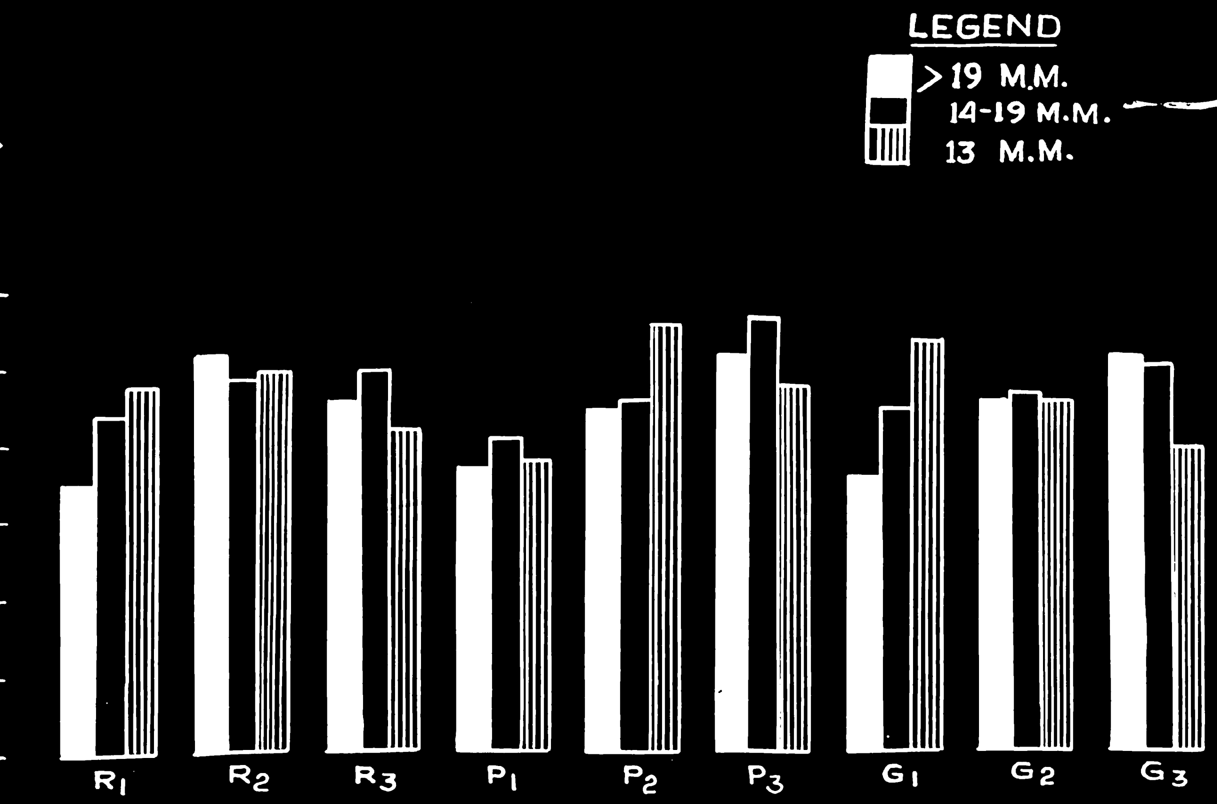


FIG.19. WEIGHT OF TUBERS PER HILL.

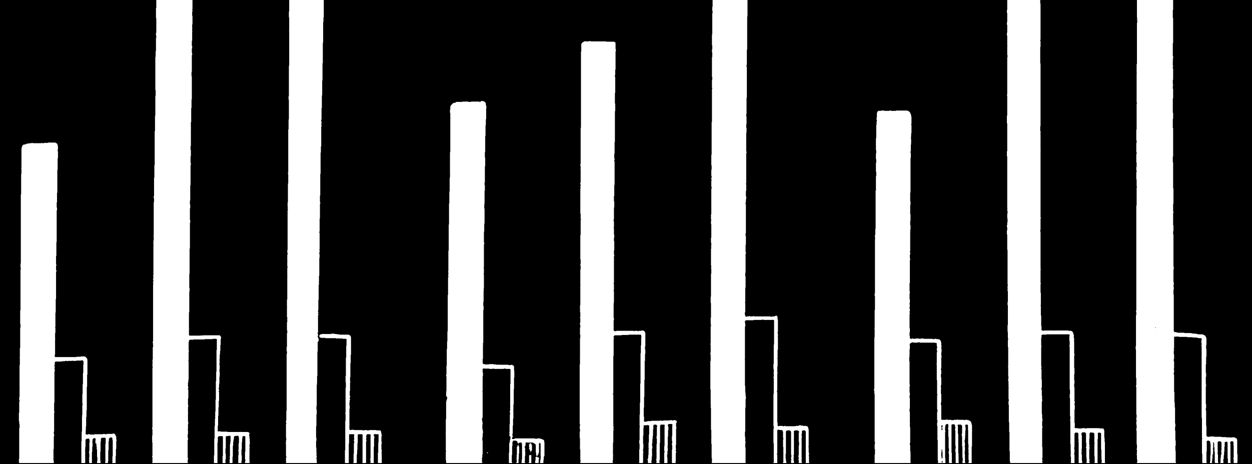


Table -15(b)

Percentage of different grades of tubers in the produce.*

Treatments.	Weight basis. G.I.	G.II.	G.III.	Number basis. G.I.	Gr.II.	I£r.
R.levels.						
R_1	68.5	24.0	7.5	27.8	34.3	37.9
R_2	74.2	19.8	6.0	34.5	32.5	33.0
R_3	74.7	19.8	5.5	33.4	36.2	30.4
P.levels.						
P_1	73.1	20.8	6.1	32.0	35.5	32.7
P_2	71.0	21.8	7.2	30.8	31.4	37.8
P_3	74.2	20.3	5.5	33.3	36.2	30.5
G.levels.						
G_1	68.2	23.3	8.5	26.3	33.[illegible]	40.2
G_2	74.0	20.1	5.9	33.1	33.6	33.3
G_3	75.3	19.8	4.9	39.6	30.7	29.7

* Figures in the body of the table represents the calculated percentage.

tubers produced increased as the size of the seed tuber increased from G_1 to G_3 in both the analytical data i.e. on sample and per hill bases.

Row space - For row spacing it was found that 40 cm. was significantly superior to 60 cm. and 80 cm. and the latter two were at par in case of sample basis. Reverse was the case with the number of grade II tubers produced per hill, where the number of tubers decreased with increased spacings from 40 cm. to 80 cm.

Plant space - Regarding the plant spacings the trend of increase in yield of number of grade II tubers was similar to that of row spacings. In case of sample basis the yield of number of grade II tubers decreased as the spacings increased from 15 cm. to 25 cm. but the opposite results were found in case of per hill basis where the increased number of grade II tubers were associated with the increased plant spacings.

Interaction - No significant differences were found due to treatment combinations.

iii) <u>Grade III.</u>

Seed tuber size - The statistical analysis revealed that the yield of grade III tubers decreased as the seed tuber size increased from G_1 to G_3 ib both cases of per sample and per hill bases. In neither cases the treatment differences were significant.

Row spacing. - In case of row spacing 40 cm. was significantly superior to 60 cm. and 80 cm. where the latter two were at par in case of sample basis. But regarding per hill basis 40 cm. was found to produce more number of grade III tubers than 40 cm. and 80 cm. without any significance in the differences due to treatments.

Plant space - So far as the yield of grade III tubers was concerned, 20 cm. gave maximum number of grade III tubers followed by 25 cm. and 15 cm. in both cases. But in case of sample basis 15 cm. gave more number of grade III tubers than 25 cm. but the reverse was the case per hill where 25 cm. gave more number of tubers than 15 cm.

Interaction - There is no significant difference due to any set of treatment combinations in relation to the yield of number of grade III tubers either per sample or per hill basis.

3. Specific gravity.

The statistical analysis of data on specific gravity reveals that there were no significant differences in specific gravity due to the different treatments.

However, from the trend it was found that the small seed tubers yielded the tubers of significantly more specicific gravity than medium and large seed tubers as found in table number 16 and Fig.13.

Table 16.

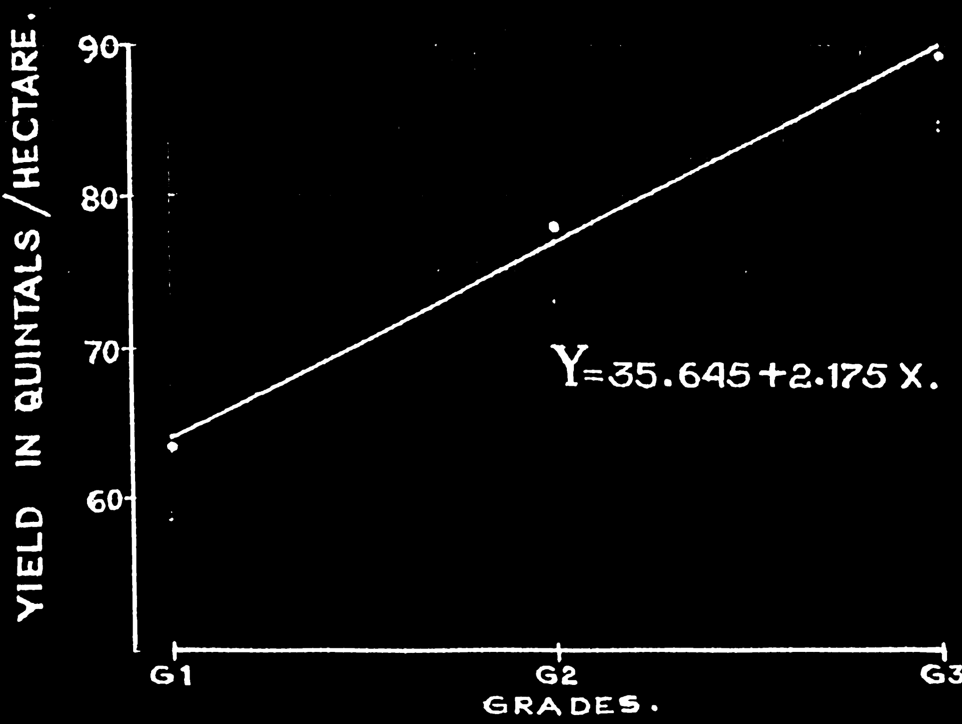
Average specific gravity of tubers.

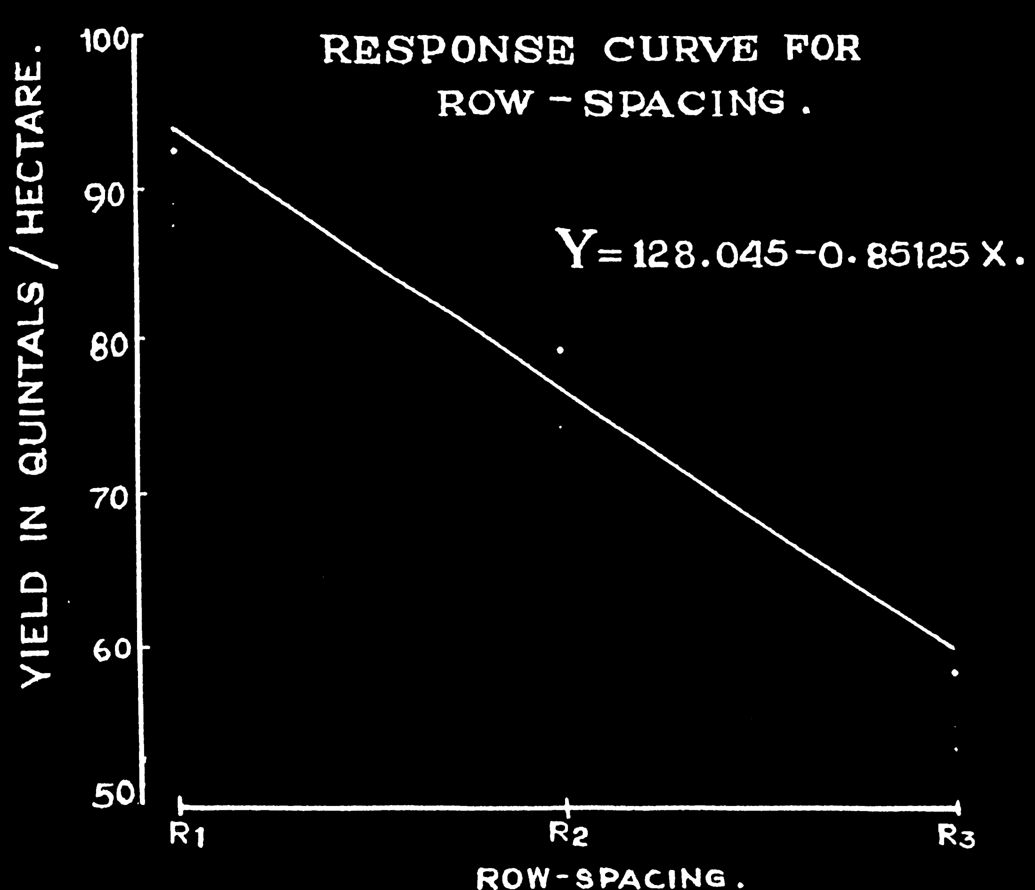
Treatments.	Specific gravity.	'F' test.	S.E(m).
R.levels.			
R_1	1.0703		
R_2	1.0668	N.Sig.	
R_3	1.0712		
P.levels.			
P_1	1.0672		
P_2	1.0703	N.Sig.	± 0.0027
P_3	1.0697		
G.levels.			
G_1	1.0708		
G_2	1.0681	N.Sig.	
G_3	1.0691		

In case of row spacing 80 cm. gave a slightly higher specific gravity than 40 cm. and 60 cm. Comparing the treatments of plant spacing 20 cm. was found to be the best. 15 cm. gave higher specific gravity than 25 cm.

No interaction was found to be significant regarding the specific gravity of the tubers. The small grade tubers in combination with maximum row spacing indicated the maximum specific gravity to the extent of 1.0778.

FIG.20. RESPONSE CURVE FOR GRADES.





Response curves fitted to various levels of row and plant spacing and seed tuber size.

Table 17.

Source.	D.F.	S.S.	M.S.	Cal.'F'	Nature of response curve.	Response curve equation.
Row-spacing.						
R.linear.	1	10,440.7524	10,440.7524	77,1280 *	Linear	Y= 128.04500 - 0.85125 X
R.Quadratic	1	175.5165	175.5165	1.2966		
R.Total	2	10.616.2689				
Plant spacing.						
P.linear	1	144.5204	144.5204	1.0676		
P.Quadratic	1	7.3060	7.3060	0.0540		
P.Total	2	151.8264				
Seed size.						
G.Linear	1	6128.2803	6128.2803	45.2709*	Linear	Y = 35.645 + 2.175 X
G.Quadratic	1	34.8616	34.8616	0.2575		
G.Total	2	6163.1419				
Error	22	2978.1190	135.3690			

The response curve equations were arrived at by the formula - $Y = a + bx$, where 'Y' represents expected yield, 'a' the yield at first level, 'b' the regression constant and 'x' the level.

* Significant (0.05)

Response curve and Economics of production:

Response curves for A and G.

Response curves were worked out in order to assess the nature of responses at three levels each of row space and seed size.The equation of the response curves are given under the last column of the table 17. From the variance table the nature of response curve for row space was found to be negatively linear i.e. with the increase in row space, the yield decreased from 92.72 Q./ha. to 58.67 Q./ha. respectively. But the narure of response curve for seed size showed a positive linearity i.e. with the increase in size of seed from 13 mm. to 25 mm. yield increased from 63.35 Q./ha. to 89.45 Q./ha. respectively.

Economics of production.

It is essential that the recommendations of spacing and seed size should be based not only on the results of higher yield but also should give higher net yield.

The table 18 clearly shows that the economics of production of potato by planting three different sizes of seed at three different levels each of row and plant spaces independently and in their all possible combinations.The net returns per hectare were calculuted by deducting the totalcost of production from the value of gross returns. The figures of gross returns were calculated by adding up the valuation figures for three grades of tubers in the produce at the prevailing market rates

Table - 18.

Economics of Production per hectare.

Sl. No.	Treatments.	EXPENDITURE IN Rs.: Labour cost.	Material cost.	Interest on working capital.	Land Revenue.	Total.	GROSS RETURNS IN Rs.: Yield in Quintals. G.I Large.	G.II Medium.	G.III. Small.	Valuation of produce in Rs. GI. Large.	G.II. Medium.	G.III. Small.	Total value of produce.	Net return in Rs.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
1.	$R_1P_1G_1$	670.16	1284.95	60.78	12.50	2018.39	53.96	16.91	9.67	2698.00	507.30	116.04	3321.34	1302.95
2.	$R_1P_1G_2$	670.16	1858.37	79.02	12.50	2620.05	70.75	28.85	5.68	3537.50	865.50	168.16	4471.16	1851.11
3.	$R_1P_1G_3$	649.11	2545.41	100.49	12.50	3328.56	77.88	33.18	4.16	3894.00	995.40	59.92	4949.32	1620.76
4.	$R_1P_2G_1$	649.11	1186.21	57.35	12.50	1905.17	51.26	24.94	9.80	2563.00	738.20	117.60	3418.80	1513.63
5.	$R_1P_2G_2$	649.11	1622.01	70.97	12.60	2354.59	54.51	23.08	11.18	2725.50	692.40	134.16	3552.06	1197.47
6.	$R_1P_2G_3$	649.11	2136.53	87.05	12.50	2885.19	86.60	17.28	5.46	4330.00	518.40	65.52	4913.92	2028.73
7.	$R_1P_3G_1$	577.00	1131.40	53.39	12.50	1774.29	39.08	16.37	57.99	1954.20	491.10	695.88	3140.98	1366.69
8.	$R_1P_3G_2$	577.00	1481.41	64.33	12.50	2135.24	62.79	24.65	4.56	3139.50	739.50	54.72	4933.22	1797.98
9.	$R_1P_3G_3$	577.00	1892.57	77.17	12.50	2559.24	71.95	18.22	3.76	3597.50	546.60	45.12	4189.22	1629.98
10.	$R_2P_1G_1$	613.25	1099.11	53.51	12.50	1778.37	36.33	11.51	8.58	1816.50	345.30	102.96	2264.76	486.39
11.	$R_2P_1G_2$	613.25	1490.66	65.74	12.50	2182.50	74.72	14.65	3.33	3736.00	439.50	39 .69	4215.19	2033.04
12.	$R_2P_1G_3$	613.25	1951.22	80.14	12.50	2857.11	63.49	17.49	3.90	3174.50	524.70	46.80	3746.00	1088.89
13.	$R_2P_2G_1$	588.05	1039.88	50.84	12.50	1690.47	41.86	17.42	8.24	2093.00	522.60	98.68	2714.28	1023.81
14.	$R_2P_2G_2$	588.05	1333.34	60.04	12.50	1993.93	57.31	13.91	4.39	2865.50	417.30	52.68	3335.48	1341.55
15.	$R_2P_2G_3$	588.05	1678.38	70.83	12.50	2349.76	69.47	14.63	4.05	3473.50	438.90	48.60	3961.00	1611.24
16.	$R_2P_3G_1$	575.51	1003.41	49.03	12.50	1640.45	46.98	18.76	3.75	2349.00	542.80	45.00	2926.80	1286.35
17.	$R_2P_3G_2$	575.51	1237.58	56.66	12.50	1882.25	64.10	18.19	4.32	3205.00	545.70	51.84	3802.54	1920.29
18.	$R_2P_3G_3$	575.51	1513.46	65.28	12.50	2166.75	75.79	14.52	3.95	3789.50	435.60	47.40	4272.50	2105.75
19.	$R_3P_1G_1$	579.41	1021.89	50.04	12.50	1663.84	36.88	9.32	3.36	1844.00	279.60	40.32	2163.92	500 .08
20.	$R_3P_1G_2$	579.41	1316.15	59.24	12.50	1697.30	45.29	9.93	2.93	2264.50	297.90	35.16	2597.56	900.26
21.	$R_3P_1G_3$	579.41	1661.19	70.02	12.50	2323.12	49.35	12.94	1.78	2457.50	388.20	21.36	2887.06	563.94
22.	$R_3P_2G_1$	570.57	977. 52	48.38	12.50	1608.97	42.52	13.04	3.17	2126.00	401.20	38.04	2565.24	956.27
23.	$R_3P_2G_2$	570.57	1197.59	55.26	12.50	1835.92	34.94	10.72	3.97	1747.00	321.60	47.64	2116.24	280.32
24.	$R_3P_2G_3$	570.57	1456.75	63.35	12.50	2103.17	52.52	16.79	4.32	2626.00	503.70	51.84	3181.54	1078.37
25.	$R_3P_3G_1$	562.12	949.68	47.24	12.50	1571.54	30.60	6.15	2.62	1534.50	184.50	19.44	1738.44	166 .90
26.	$R_3P_3G_2$	562.12	1124.63	52.71	12.50	1751.96	42.55	8.72	1.92	2127.50	261.60	23.04	2412.04	660.08
27.	$R_3P_3G_3$	562.12	[illegible]	54.06	12.50	1958.51	57.46	18.29	5.19	2873.00	548.70	62.28	3483.98	1525.47

Th-561.

50,30 and 12 rupees per quintal for large, medium and small tuber grades respectively.

It is seen that the maximum net return of Rs.2033.04 was obtained due to planting of large seed at a spacing of 60 cm. x 25 cm. though maximum yield of tubers produced was due to large tubers closely planted at a spacing of 40 cm. x 15 cm.

Table 18(a).

Mean net return (Rs. / ha).

	R_1	R_2	R_3	Mean.	G_1	G_2	G_3
P_1	1591.61	1202.77	654.76	1149.72	763.14	1594.80	1091.26
P_2	1579.94	1325.53	771.65	1225.71	1164.57	939.73	1572.78
P_3	1598.21	1770.80	784.15	1384.38	939.98	1459.45	1753.73
Mean	1589.92	1433.03	736.85	1253.27	955.89	1331.34	1472.57
G_1	1394.42	932.18	541.08	955.89			
G_2	1615.52	1764.96	613.55	1331.34			
G_3	1579.82	1601.96	1055.93	1472.57			
Mean	1589.92	1433.03	736.85	1253.27			

R_1 - 40 cm.
R_2 - 60 cm.
R_3 - 80 cm.
P_1 - 15 cm.
P_2 - 20 cm.
P_3 - 25 cm.
G_1 - Small.
G_2 - Medium.
G_3 - Large.

When main effects were considered from table above it was found that with increase in row space from 40 cm. to 80 cm. the net return decreased. The net return increased with the increase in the size of seed but the corresponding increase in net return due to plant ...es was not found to vary to any marked extent.

DISCUSSION

The present investigation on the effects of the three levels each of seed tuber size, row and plant space included studies on the growth and yield of potato. The yield of these products is the resultant of various metabolic processes in the plant body affected by a number of environmental and agroclimatic factors. Among the various factors, spacing and seed size are two most important ones which have profound influence on the growth of plants and total produce. As reported by various workers there is direct correlation of spacing and seed size with the yield. The concensus of opinion is that the tubers ultimately produced and the proportion of different tuber fractions contained in it are the results accruing from adopting optimum spacing and seed size. The result of the investigation brought to light certain salient points which are discussed in this chapter.

Germination:

Size of the seed has shown a remarkable influence on the germination and final plant population. Maximum germination percentage of 84.60 was observed in case of large seeds giving thereby 7% and 5% more germination than the small and medium seeds respectively. In general from table 3 and Fig. 3 and 11 it is noticed that the germination was not very satisfactory in the initial growth stages. Finally the plant population has also been found to be influenced by seed size. The reason accountable for the depression in germination by smaller tubers is probable due to the fact that the tender portion of germinating shoot over-ground received earlier a set back when they were below the soil surface due to competition for limited availability of reserve food materials. This tendency of depression was maintained all throughout the growing period which is in close collaboration with the results obtained by Bates (1935) and Pushkarnath, et al. (1963).

It was noticed that out of three row spacings tried in the experiment 60 cm. space gave more germination and final plant population as compared to 80 cm. and 40 cm. space. Similarly out of the three plant spaces 20 cm. gave more plant population than either 25 cm. or 15 cm. It is presumed that the germination in case of too close or too wide spacing was depressed perhaps due to heavy competition or imperfect utilization of plant food available in the soil.

Number of shoots per hill:

A glance at table 4 and Fig.4 reveals that the large seeds produced more number of shoots than the smaller ones which can be well explained by the fact that the planting of large seeds containing more reserve food materials for plant metabolism, results in better development in growth which is manifested by way of more number of shoots produced. This finding confirms the results obtained by Kapoor (1951), Roer (1957) and Suri (1963). However, it was noticed that 25 cm. plant space in combination with large seed gave maximum number of shoots per hill.

Height:

It was found that with the increase in the size of seeds the height of the plants increased though towards the later part of plant growth, it remained almost constant, though no differences were significant due to the different seed size. The large seed because of its more food reserve helps in better vigour of the plants initially resulting in elongation of internodes. Similar results were reported by Chandra (1961) who found out that as the seed size increased more vigorous plants were produced.

The study of data in table 5 and Fig.7 indicates that the rate of increase in plant height in general was more during the period from 45 days to 55 days and the same trend of increase in growth rate during the period resulted from planting of large seeds only. The growth was faster during this period due to dominant growth of meristems. This period perhaps coincided with the peak period of growth.

The plant spacings were found to exert no influence on the height of the plants which confirms the result obtained by Singh and Alhawat (1955) who have formulated that spacings had no effect on the plant height. However, it is seen that with the aging of the plants in general the height increased though at a reduced rate.

Number of leaves:

Significant differences in leaf number per plant were found due to the seed size fairly in early stages up to 65 days and as the seed size increased from 13 mm. to 25 mm. there was increase in number of leaves perhaps due to more photosynthetic activities to cope with the heavy requirement of foods by plants. This finding is at par with the results reported by Suri (1963). After a short rise in plant height up to 75 days there was fall in the number of leaves per plant resulting from the shedding of lower leaves.

It is noticed that the spacing had no effect on the number of leaves.

Leaf area:

From table 7 exhibiting the data on the area of leaves it was found that neither of three main factors i.e. row and plant spaces and seed size had any appreciable effect on the leaf area measured only at a later growth stage.

Stem girth:

As seen from table 8 and Fig. 5 it was found that the stem girth increased with the increase in seed size in initial growth stages and later on there was reduction in the girth. The stem girth attained its maximum stage at 65 days after planting irrespective of the seed size indicating the vigorous growth of the plant. The reduction in the stem girth almost at the end of maturity stage was due to the shrinkage of cells. The rate of reduction in stem girth was more with the large seeds. This fact can be well explained by the phenomenon of senescence. Earlier at 65 days the girth reached its maximum stage due to more expansion in cell size perhaps as a result of maximum turgidity created in the cells.

As the turridity with maturity of the crop reduced there was reduction in the stem girth. Because of more vigorous plants were produced by planting larger seeds which also germinated earlier the rate of reduction in stem girth was more as compared to smaller seeds. There was very little difference in stem girth before the harvest of the crop.

The row and plant spaces also had the similar effect of the stem girth in all stages of plantr growth as did the seed size. It increased with the increase in plant spacing at 65 days after planting.

Number of branches per hill:

The close perusal of the data presented in table 9 and Fig.8 clearly show that small tubers produced maximum number of branches and ultimately the seed size exerted a profound influence.The reason is that the single sprouts with apical dominance are produced from large tubers on the surface of which eye spots are distributed wide apart. In case of small tubers with eye spots clos ely distributed multiple sprouts having no apical dominance are produced which give more branches (Thomas,1960).

Row spacing was also found to exert influence on the number of branches per hill and wider the row spacing more were the number of branches and 70 cm. space produced about 22% more branches than did the 40 cm. , the closest tried. Plant spaces were found to have no influence on the number of branches.

Incidence of virus:

Seed size on an average caused the infection of rugose mosaic (Robert 1955) to the magnitude of about 11% of the plant. The difference in virus infection due to seed size was not marked though there was a tendency of providing more security by planting large tubers. It is a fact that because of virus infection in potato smaller seeds carrying the inoculum are produced. These seeds which look apparently disease free when planted produce disease symptoms and hence plants produced from small seeds are badly affected. This is in quite agreement with the findings reported from Kanpur and Farrukabad (1956) in India and West Germany (1957) where it is mentioned that the resistance offered by large tubers were more than the small ones. The influence of spacing was significant and wider spacing caused more infection than the closer ones. This can be explained that in case of wider spacing insect vectors infected more number of plants than they did in closer spacing where there was thick stand.

Root length:

Seed size and plant spacing exerted some amount of influence on the length of roots. Large tubers and closer spacing produced the longest roots. In both the cases because of large number of shoots there was more quest by roots for moisture and nutrients to be drawn from the deeper soil zone, which resulted in longer roots.

Weight of dry haulm:

It was found (Table 12 and Fig.12) that larger the seed size more was the production of dry haulm, which is in conformity with the finding by Kapoor (1951) who indicated that the weight of tops increased with the increase in seed size. Similarly more dry haulm was the result of planting tubers wider. In all these cases more number of shoots, more stem girth and tall plants were produced which have direct reflection on the ultimate weight of the dry haulm.

Total yield:

Seed size when considered as a main independent factor had a tremendous effect on the total yield of tubers produced per hectare (Table 13 and Fig.15). Maximum yield was produced by planting large tubers and it gave significantly higher yield to the extent of 30% more than the small seed. Such increased yield was attributable to the early emergence and better development of growth components resulting from vigorous photosynthetic activities which are responsible for synthesis, transmission and storage of starch and proteins in the tubers. The results were quite in agreement with those obtained by Salaman (1923), Findly and Sykes (1930), Sing and Wakankar (1943), Wakankar (1944), Burton (1948), Singh, et al. (1952), Harrington (1952), Werner (1954), Boer (1957), Ariyanayagam (1958), Antchev (1959), Chandra (1961), Singh et al. (1961), Patil (1961), Suri (1963) and Chaudhuri and Chaudhuri (1968) who reported that tuber yield could be raised by planting large seeds.

It was noticed that a closed row space of 40 cm. enormously increased the total yield of tubers giving to the magnitude of about 40% response over 80 cm. for the obvious reason of more number of hills on unit area basis. Such finding is not rare and confirms the results reported earlier by Stuart (1928), Bates (1935), Jannaccone (1957), Mc.Cubbin (1957), Bishop and Wright (1959), Chandra (Loc.cit.) Brember, et al. (1962) and Tiwari (1962) who emphasized that the yield increases were due to decrease in row space.

Though significant yield differences were not obtained, closer inter plant spacing tended to increase the yield per unit area basis. Harrington(1951), Ingebrigtsen (1953), and Montague and Ivins (1955) supported this inference and stated that there was reduction in yield as the interplant space increased.

From general yield figures per hectare it is noticed that large seed planted at a spacing of 40 cm. X 15 cm. gave the maximum out-turn of about 115 quintals of tubers per hectare which contradicts the finding by Singh (1952) and Duijendijk (1954) who argued that planting of large tubers at a closer spacing was risky.

Grades of produce:

A study of figures 16 to 19 and tables 14 and 15 reveals that weight and number of tubers irrespective of their fractions per unit area basis increased with the decrease in row spacing and also decrease in the plant spacing. But weight and number of ware and seed fractions increased with increase in seed size. It is possible that the smaller seeds manifested more infection of virus which was responsible for higher chat fractions in the produce.

When individual hills were considered the increases in weight and number of ware and seed fractions were associated with the increase in plant space independently with a corresponding decrease in chat fractions with increase ~~in plant space and~~ tuber size. Weight and number of tuber fractions also increased with increase in row space.

Percentage of ware fractions (Table 15 b.) increased and that of chat and seed fractions decreased with increased row and plant space. This result was in accordance with those obtained by Bates (1935), Findlay and Sykes (1938) Chucka, et al. (1945) and Flamini (1957) who have found out that wider spacing increased the yield of ware tubers and the closer spacing increased the tubers below marketable size. Percentage of seed and chat fractions decreased and ware fractions increased with increase in seed size. This result is inconformity with that obtained by Llaveria and Montalvo (1958) who reported that larger the seed size more were the consumable ware tubers. Workers like Singh, et al.(1961), Singh and Wakankar (1943), Kapoor (1951) and Verma (1953) contradicted by reporting that larger the seed tubers less were the percentage of ware fractions.

Specific Gravity:

From the present investigation it is noticed vide table 16 that specific gravity of tubers produced was slightly higher in wider spacing than closer spacing. The increase in specific gravity with wider spacing may be attributed to a reduced uptake of fertility elements especially nitrogen and Potash. With a wider spacing the plants were vigorous and each individual plant could secure only the supply of small amounts of fertility elements. It is well known that an increase in supply of nitrogen and potash tends to decrease the specific gravity of potato tubers. Contradicting results were reported by Sanborn in as early as 1891.

Seed sizes also were found to vary with respect to their effect on specific gravity. Small seeds produced tubers of slightly higher specific gravity than the larger ones which is probably associated with the longer growing period available for photosynthetic activities resulting in tubers of more advanced maturity and therefore of higher specific gravity. It was especially true that the natural death of the vines, from close observation in the field occurred later in case of smaller seed and the plants remained green for a comparatively longer period. Such generalisation was given by Gruner (1963) who opined that the course of absorption of nutrients, their translocation and assimilation is regulated by the length of time taken to reach maturity.

Yield response and economics of production:

It was found that due to the increase in seed size yield increased showing a linear trend but a negative linearity was observed where with the increase in the row space there was a decrease in yield. It can therefore be inferred that still higher levels of seed size and lower levels of row space are to be tried for securing higher yields.

The net monetary return was found to be maximum by planting larger seed at a spacing of 60 cm. X 25 cm. and this return was more than that obtained due to planting of large seed at a close spacing of 40 cm X 15 cm. where though the yield was maximum the net return was less by Rs.412.28 than the former. This reduction in net return due to close planting of large tubers was associated with the increased cost of production by way of additional expenditure incurred on planting in close spacing which requires more seed rate.

When the individual factors were considered it was found that the net return increased with the increase in seed size but decreased with increase in row space which are directly associated with the yield. But with the inerease in plant space the net return increased which was inversely associated with the yield.

SUMMARY AND CONCLUSION

The present investigation was undertaken in the Farm of Agronomy Division during the Rabi 1963-64 to study the effect of three level each of row space, plant space and seed size independently and in all possible combination on the growth and yield of potato crop. A delicious late variety Red Patna was included in the investigation. The three row spaces were 40 cm., 60 cm., and 80 cm., and plant spaces were 15 cm., 20 cm. and 25 cm. The small (G_1), medium (G_2) and large (G_3) sizes are numerically represented as - below 13 mm., 13 mm. to 19 mm. and 19 mm. to 25 mm. respectively Uniform fertilizer application was done to supply 80 kg. 160 kg., and 80 kg. respectively of N.P.K. per hectare. The experiment was conducted in a 3^3 confounded factorial design replicated twice. The results obtained from the present investigation and conclusions drawn are stated below.

1. Size of seed in different levels significantly increased total yield of tubers. The gross yield of tubers increased significantly with the increase in size of tubers. The seed size of 25 mm. increase the yield to the tune of 30% over 13 mm. size, The yield also increased with the decrease in row space. The close row space of 40 cm. enormously increased the yield to the extent of 40% over 80 cm. Interplant space alone was found to be ineffective.

The treatment combination of large seed planted ata spacing of 40 cm. X 15 cm. gave the maximum yield of 115 quintals of tubers per hectare.

2. Large seed induced early emergence giving higher percentage of germination and proved five percent to seven percent more effective than medium and small seeds respectively. A depression in germination was found due to too wide or too close spacing.

3. As the seed size increased from 13 mm. to 25 mm. the number of shoots per hill increased. Planting space alone was found not to exert any influence on the number of shoots but wide plant space (25 cm.) in conjunction with large seed produced significantly more shoots per hill.

4. In initial growth stages the plant height increased with the increase in seed size. The maximum rate of increase irrespective of the treatments coincided with grand period of growth i.e. from 45 days to 55 days after planting. Spacing was found to be ineffective.

5. With the increase in the size of the seed from 13 mm. to 25 mm. there was increase in number of leaves per hill and stem girth. Spacing was found not to influence the number of leaves but with the increase in spacing stem girth increased. Small seeds were found to be very effective in producing maximum number of branches per hill. The seeds planted in lines 80 cm. apart proved to be effective in producing number of branches by

22 percentagens compared to 40 cm. space. Large tubers closely planted tended to induce the formation of long roots.

6. Large seed tubers were found to provide some amount of security with respect to virus-infection. Incidence of virus was more pronounced with the wider spacing.

7. Wider spacing or larger seed resulted in the increase in number and weight of ware and seed fractions in the produce. Percentage of ware fractions also increased with increase in spacing and seed size which suggest that for producing marketable tubers large seed may be planted wider. More chat fractions were produced due to small seed. As the seed size and spacing increased total dry haulm produced was higher.

8. Seed size and spacing were found to exert a little influence in the specific gravity of tubers produced. However, smaller seeds and wider spacing tended to slightly increase the specific gravity.

9. Planting of seed with the increasing sizes increased the yield of tubers and also a positive linearity in response was observed siggesting further that seed sizes beyond 25 mm. are worth-while to be included in future trials to obtain still higher yields. Planting of seeds with the decreasing row spaces increased the yield of tubers and a negative linear

response was observed which suggests that row spaces lower than 40 cm. are to be tried for getting higher yields.

10. Maximum monetary net profit of Rs.2,033.04 per hectare was accrued from planting large tubers at a spacing of 60 cm. X 25 cm. The possibility of obtaining higher monetary net returns exists with the planting of seeds larger than 25 mm. in size. Also possibility does exist to plant tubers at row spaces lower than 40 cm..

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* Original not seen.

APPENDIX.

Table - 1.

Germination and other characters.

Sources.	D.F.	VARIANCE. Germination. 1st.	2nd.	3rd.	Final Plant population.	No.of branches.
Blocks.	5	1.910	21.568	20.388	8.6829	12.9692
Replications.	1	0.480	3.630	0.340	4.0617	17.3400
Within replication	4	2.288	28.053	25.423	9.8382	11.8765
N	2	6.320*	275.475*	109.875	40.6091	21.0365*
P	2	0.635	160.305	106.550	37.5002*	12.5525
G	2	34.595*	977.755*	240.045*	153.4504*	26.0225*
NP	4	1.105	7.848	20.580	9.2291	2.6530
NG	4	1.495	24.003	16.713	12.5695	6.3190
PG	4	1.123	55.815	66.995	35.9347	2 .6535
NP^2G^2(W)	2	0.225	141.950	98.215	44.2738	0.1160
NP^2G (X)	2	5.105	24.255	16.680	5.3096	3.2180
NPG^2 (Z)	2	0.400	13.770	28.525	8.2635	3 .7605
Error	22	1.515	74.820	55.601	26.0716	5.5485
Total	53					

* Significant (0.05)

Table - 2.

Number of shoots at successive growth stages.

Sources.	D.F.	VARIANCE. 1st.	2nd.	3rd.	4th.	5th.
Blocks.	5	0.0474	0.0798	0.0794	0.0680	0.0502
Replications	1	0.0260	0.0090	0.0180	0.0740	0.0360
Within replication	4	0.0528	0.0975	0.0948	0.0865	0.0538
R	2	0.0005	0.0340	0.0285	000070	0.0420
P	2	0.0945	0.1205	0.1085	0.2360*	0.1755*
G	2	6.0115*	5.5090*	5.6505*	3.5830*	1.7430*
RP	4	0.1658	0.1185	0.1080	0.0620	0.0145
RG	4	0.0290	[illegible]	0.0288	0.0103	0.0065
PG	4	0.1595	0.1553	0.1638	0.1965*	0.0533
RP^2G^2 (W)	2	0.0300	0.0195	0.0195	0.0415	0.0670
RP^2G (X)	2	0.1545	0.1045	0.1360	0.1900	0.1070
RPG^2 (Y)	2	0.1905	0.2240	0.1935	0.1470	0.0535
RPG (Z)	2	0.1685	0.1355	0.1070	0.0890	0.0050
Error	22	0.100	0.1092	0.1058	0.0610	0.0363
Total	53					

* Significant (0.05)

Table - 3.

Height of Plants at Successive growth stages.

Sources.	D.F.	VARIANCE. 1st.	2nd.	3rd.	4th.	5th.
Blocks.	5	50.095	14.252	30.6178	32.3226	221.5588*
Replications	1	177.488*	56.016	74.9060*	150.6670*	666.4090*
Within replication	4	18.244	8.811	19.5458	9.9915	96.5962*
R	2	56.104	5.690	16.7935	54.5850	16.4445
P	2	0.887	10.186	33.0065	25.9625	28.8145
G	2	333.777*	412.037*	177.3615*	77.2080*	45 .5790
RP	4	2.454	2.053	4.8908	5.2270	35.1525
RG	4	20.969	14.705	13.6175	2.1985	10.7637
PG	4	6.640	22.283	47.1235*	29.5863	32.9812
RP^2G^2 (W)	2	7.912	18.716	2.6180	5.3690	12.6980
RP^2G (X)	2	13.654	34.175	2.2935	0.1895	48.1335
RPG^2 (Y)	2	0.468	5.383	8.3035	3.8905	18.3785
RPG (Z)	2	2.028	13.102	1.6260	5.1170	4 .0035
Error	22	21.549	12.832	13.4955	18.1768	14.9256
Total	53					

* Significant (0.05)

Table - 4.

Number of leaves at successive growth stages and leaf area.

Sources.	D.F.	VARIANCE. 1st.	2nd.	3rd.	4th.	5th.	Leaf area.
Blocks.	5	40.771	60.224	346.0492*	793.7020*	142.0018	2039.0328*
Replications.	1	187.420	92.304	1564.9350*	139.2010	114.1150	8178.0260*
Within replication	4	4.108	52.204	41.3278	957.3248*	148.9735	504.2845
R	2	95.000	65.878	1038.0615*	2121.4865*	394.7120	220.7555
P	2	93.930	229.366*	724.1850*	3251.0680*	1324.3410*	132.5560
G	2	1055.277*	586.828*	304.3815*	97.3790	715.4565	34.0890
RP	4	45.132	15.777	53.2935	136.7133	54.4768	52.3815
RG	4	57.330	29.291	51.0068	499.1120	220.2790	74.8555
PG	4	87.125	85.260	20.8268	339.2920	160.4762	87.5618
RP^2G^2 (W)	2	21.371	152.732	3.9145	190.4100	191.3755	23.5190
RP^2G (X)	2	26.673	58.156	7.1245	62.7115	80.1405	47.8125
RPG^2 (Y)	2	58.682	52.272	6.1665	217.1760	19.2410	623.0850
RPG (Z)	2	106.711	61.254	43.2055	54.2865	436.3585	618.9155
Error	22	51.702	43.198	49.4422	241.6227	237.8846	286.0911
Total	53						

* Significant (0.05)

Table - 5.

Stem girth at successive growth stages.

Sources.	D.F.	VARIANCE 1st.	2nd.	3rd.	4th.	5th.
Blocks.	5	0.010270*	0.003994	0.002880	0.004154*	0.028404*
Replication	1	0.010700*	0.000120	0.000030	0.000170*	0.068980*
Within replication	4	0.010163*	0.004962*	0.003592	0.005150*	0.018260*
R	2	0.001810	0.004010	0.004550*	0.001665*	0.011770
P	2	0.004925	0.001000	0.001570	0.000490*	0.009215
G	2	0.023180*	0.002245	0.002685	0.000105*	0.000420
RP	4	0.002103	0.000350	0.000740	0.000588*	0.006990
RG	4	0.003892	0.000980	0.000625	0.000323*	0.004280
PG	4	0.002510	0.000100	0.000523	0.000563*	0.004288
RP^2G^2 (W)	2	0.004900	0.004015	0.003115*	0.001425*	0.001130
RP^2G (X)	2	0.001650	0.002235	0.000915	0.009800*	0.003215
RPG^2 (Y)	2	0.002960	0.002415	0.001870	0.000995*	0.003315
RPG (Z)	2	0.000815	0.003660	0.001815	0.000850*	0.006370
Error	22	0.002452	0.001382	0.000788	0.000030	0.004274
Total	53					

* Significant (0.05)

Table - 6.

Total tuber yield and other characters.

Sources.	D.F.	VARIANCE. Yield of tubers.	Specific gravity.	Virus Count.	Root length.	Dry haulm.
Blocks.	5	697.0068*	0.00018	0.07126	2.3870	12.5740
Replications.	1	3113.1620*	0.00028	0.01900	1.4670	15.0420
Within replication.	4	92.9680	0.00021	0.08433	2.0920	11.9525
R	2	5312.6345*	0.00014	0.22089*	0.9815	210.7025*
P	2	80.4135	0.00007	0.22894*	10.7015	81.6475*
G	2	3086.0710*	0.00003	0.03456	4.3350	72.3090*
RP	4	235.5945	0.00027	0.59484*	5.0235	13.7335
RG	4	133.9410	0.00011	0.23900*	6.2583	38.1360*
PG	4	266 .8790	0.00019	0.03331	1.9910	14.3253
RP^2G^2 (W)	2	38.1450	0.00002	0.08117	3.3440	17.1470
RP^2G (X)	2	57.7425	0.00001	0.01667	0.3835	9.9300
RPG^2 (Y)	2	7.9000	0.00010	0.03814	5.4215	4.1455
RPG (Z)	2	105.3365	0.00007	0.05195	1.3650	6.4970
Error	22	135.3690	0.00012	0.03870	5.4247	6.6800
Total	53					

* Significant (0.05)

Table - 7.

Weight of tubers of different grades.

Source.	D.F.	VARIANCE. Per sample. Gr.I	Gr.II.	Gr.III.	Per Hill. Gr.I.	Gr.II.	Gr.III.
Blocks.	5	0.1068	0.0787	0.0224*	162.486	74.908	19.906*
Replications.	1	0.0937	0.2367*	0.0948*	323.640	224.480*	80.910
Within replication	4	0.1102	0.0393	0.0043	122.198	37.515	4.655
R	2	1.3933*	0.4318*	0.0444*	2890.085*	27.985	1.795
P	2	0.2009	0.0400	0.0127	2614.930*	162.400	13.575
G	2	2.5438*	0.0264	0.0168	2100.025*	15 .775	7.830
RP	4	0.1458	0.376	0.0030	313.115	21. 913	1.443
RG	4	0.5172	0.0146	0.0093	258.738	29.000	8.123
PG	4	0.6032	0.1209*	0.0007	540.668	70.373	1.118
RP^2G^2 (W)	2	0.0115	0.0362	0.0013	1.110	22.845	2.110
RP^2G (X)	2	0.1423	0.0241	0.0050	323.395	13.975	3.170
RPG^2 (Y)	2	0.0269	0.0310	0.0038	120.800	0.990	6.240
RPG (Z)	2	0.[illegible]	0.0219	0.0027	291.975	29.590	3.565
Error	22	0.3059	0.0297	0.0051	374.778	31.360	5.797
Total	53						