EFFECTS OF PHOSPHORUS, POTASSIUM AND BORON DIM THE AGRONOMIC PERFORMANCE OF GROUNDNUT (*Arachis hypogaee* L.) IN NIGERIA

By

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for a higher degree.

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CERTIFICATION

This thesis entitled 'EFFECTS OF PHOSPHORUS, POTASSIUM AND BORON ON THE AGRONOMIC PERFORMANCE OF GROUNDNUT (*Arachis hypogaea* L.) IN NIGERIA' by Mohammed Gidado HASSAN meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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ABSTRACT

Investigations were carried out for two years each at Samaru in the Northern Guinea and Mokwa in the Southern Guinea savannah to observe the response of groundnut (*Arachis hypogaea* L.) to varying levels of phosphorus (6, 16 and 24kg P ha^{-1}), potassium (0, 20 and 40kg ha^{-1}) and boron (0.0 and 0.5kg 0 ha^{-1}).

At Samaru, increasing the level of phosphorus from 8kg to 16 and 24kg P ha^{-1} enhanced pod yield by an average of 23 and 16%, respectively. Other yield attributes such as mature pods per plont, shelling percentage and kernel weight were only slightly increased up to 24kg P ha^{-1} . In Mokwa, the application of 16kg P ha^{-1} appeared adequate for optimum groundnut production.

The addition of potassium fertilizer generally did not result in increased pod production. However, at Mokwa where the level of soil potassium was relatively low there was a tendency for increased pod yield in the presence of added potassium fertilizer.

Application of boron had no effect on groundnut production except in 1984 at Mokwa where the use of 0.5kg 0 ha^{-1} significantly increased the haulm yield.

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Chapter 1

INTRODUCTION

1.1 Origin

Groundnut (*Arachis hypogaea* L.) is a member of the family Leguminoseae. The plant is a native of south Africa and was reportedly brought to the east and west coasts of Africa by early Spanish and Portuguese explorers (Hammons, 1973).

1.2 Plant Habit

Groundnut varieties fall into two major groups:

a) the 'bunch' type which grows erect with upright branches and mature pods centered near the main stem, and

b) the 'runner' type which is spreading in growth with prostrate branches and pods scattered along the branches.

However, there are other groundnut plants that are intermediate in habit (Howes, 1948).

1.3 Soil and Climatic Requirements

The groundnut plant is known to thrive best on well-drained and friable sandy-loams with a pH range of 5.8-6.2. The plant requires a lot of sunshine and regular rainfall during the growing period. A total of at least 75.0cm of rainfall, evenly distributed over a period of about 110-140 days is usually adequate for a good crop (Yayock, 1979a; Misari *et al.*, 1982). The optimum night and day temperature for groundnut are estimated at 20 and 30°C, respectively (Fortanier, 1957).

1.4 Economic Importance

The annual world production of groundnut was estimated in 1983 (F.A.O., 1984) at 20 million tonnes, with India, China, U.S.A., Sudan, Indonesia, Burma, Nigeria and Zaire being the major producing countries, in that order.

The importance of groundnut in Nigeria lies not only in its role as a potential foreign exchange earner, but also in its use as a source of oil (contains 45 - 50% oil) and protein (25%) for the country's nutritional requirement. In addition, groundnut has important usage in the livestock industry as a source of supplementary feed. Of the estimated 59g of crude protein available per head per day in Nigeria, groundnut reportedly contributes 5% (Olayide, 1972). With the minimum daily adult requirement for protein put at 65g (Olayide, 1972), increased groundnut production can contribute in eliminating the shortfall in the protein supply.

1.5. Factors Responsible for Low Productivity

The production of groundnut in Nigeria has been on the decline since the record crops of 1966 when about 1.8 million tonnes of groundnut was produced and over one million tonnes of kernels was purchased by the then Northern Nigeria Marketing Board (Yayock, 1979a; F.A.O., 1980). Until the early 1970s, the country was the third largest producer of groundnut in the world. The decline in production has been such that as at 1977 to date the country has had to revert to importation of groundnut products, particularly oil, to meet her internal needs.

Various views have been put forward regarding factors responsible for the generally low yields of groundnut per unit area as well as the declining national out put. Among the major reasons often advanced are factors related to climate, disease epidemics and socio-economic related considerations (Anon., 1978). In addition to these factors, problems of groundnut nutrition, the *theme* of the present study, is also of importance in explaining the low level of productivity recorded in recent years.

Surveys carried out prior to mid sixties indicated that most Nigerian soils on which groundnut was produced were inherently low in phosphorus content (Goldsworthy and Heathcote, 1963) and the presence of native potassium in adequate amount was established (Hartley, 1937). However, more recent investigations have shown that continuous cropping of a piece of land have resulted in an increased demands for phosphate fertilizers than generally recommended. It also remains true that intensive cultivations of a piece of land and the continuous application of one or more fertilizer elements may, in due course, result in the deficiency of other mineral nutrients such as potassium, boron, etc. (Heathcote, 1972, Balasubramanian, et al., 1980a). Thus the need for the use of balanced fertilizer package for groundnuts cannot be over-emphasized. It is in this light that the present investigation was initiated to determine the response of groundnut to varying levels of phosphorus, potassium and boron fertilizers.

Chapter 2

LITERATURE REVIEW

It is estimated that a crop of groundnut yielding 1,200kg kernel ha^{-1} normally takes up from the soil an average of 72kg N, 7kg P, 42kg K, 15kg Ca, 9kg Mg and 6kg S per hectare (Yayock and Yusuf, 1981). Under intensive and continuous cropping of farmlands, this level of nutrient removed has a considerable exhaustive effect on the soil.

The review of literature that follows highlights the importance of the major nutrient elements on groundnut production.

2.1 Nitrogen

Nitrogen is essential for the growth of plants as it is a constituent of proteins and nucleic acids. Its deficiency usually results in reduced plant vigour and leaves as well as the development of uniform pale-green or yellowish-green leaf colour, which ultimately results in the death of the lower (older) leaves (Mathur, 1967).

Being a legume, the groundnut plant possess a special ability to fix free atmospheric nitrogen by forming a symbiotic association with one of the species of Rhizobium bacteria. In this way the plant meets its nitrogen requirement and rarely does it respond to external sources of nitrogen (Wahhab and Muhammed, 1950; Goldsworthy and Heathcote, 1963; Acuna and Sanchez, 1969; Heathcote and Stockinger, 1970; Yayock, 1979b).

Results of studies in northern Nigeria have indicated that nitrogen application to groundnut may actually depress kernel yield while consistently increasing haulm yield up to 30kg N ha^{-1} (Lombin et al., 1985). However, there have been suggestions to the effect that where the level of soil nitrogen is known to be critically low, 15-20kg N ha^{-1} may be applied as a starter dose at the time of planting in order to take care of the young plants before nodulation is established (Balasubramanian et al., 1979).

2.2 Phosphorus

Phosphorus deficiency in groundnuts normally results in stunted growth, small leaf surface with a dull bluish-green colour which in later stages becomes yellowish-green and drop. Lack of phosphorus also causes delayed ripening, poor fruiting and root growth (Mathur, 1967).

Much of the land on which groundnut crop is produced in Nigeria is invariably deficient of phosphorus and so, only phosphatic fertilizers are often recommended. Largely as a result of its greater solubility and its content of calcium (19% Ca) and Sulphur (14% S) in addition to phosphorus (8% P), Single superphosphate has so far proved the best source of phosphatic fertilizer for groundnut.

Earlier recommendation in Nigeria was to apply 8kg P ha^{-1} under the traditional semi-intensive system of agriculture. However, with the gradual change from the traditional farming system to continuous intensive cultivation, it has been shown that much higher rates are needed. This trend is more so the case with the introduction of higher-yielding varieties as well as the general improvement in crop management practices (Harkness et al., 1976; Yayock, 1978; Balasubramanian et al., 1981.

Investigations by Balasubramanian et al.(1980b) shows that an application of 20kg P ha^{-1} to groundnut may be required under continuous cultivation and good management practices. Similarly, Singh (1984) has indicated that in the Northern and Southern Guinea savanna zones response of groundnut was significant at 16-24kg P ha^{-1}. It is largely on the bases of these investigations that the present recommendation which calls for the application of 24kg P ha^{-1} was formulated.

2.3 Potassium

Groundnut plants grown on soils deficient in potassium usually exhibit necrotic scorch areas at the margin of leaflets. In later stages of growth, the stems near the tips of branches become reddish in colour, then brown and followed by the death of the tissue (Burkhart and Collins, 1941).

The potassium needs of groundnuts in most producing areas of Nigeria were considered well taken care of by the native soil potassium (Hartley, 1937). Experiments conducted by Balasubramanian et al. (1980a and 1980b) have indicated that the response of some crops, including groundnut, to applied potassium under continuous cultivation in savanna soils was negligible or **even negative.** These workers were of the opinion that the soils were rich in potassium enough to sustain continuous crop production without the need for external sources of this nutrient element.

However, responses to the applications of potassium fertilizers have been evidendenced mainly on light-textured soils developed from aeolian deposits and sandstone parent material (Anon., 1977; Anon, 1983). The need for potassium appears to be as a result of intensive and continuous cropping of farmlands (Harkness et al., 1976; Yayock, 1978). In addition, repeated application of incomplete fertilizer may sooner than later result in the deficiency of such nutrients like potassium (Jones and Stockinger, 1976). Investigations by Balasubramanian et al. (1981) and Singh (1984) reveals that the response of groundnut to applied potassium was significant in all the savanna ecological zones of Nigeria. Singh (1984) suggested the application of 20kg K ha^{-1} under continuous and intensive cultivation; indeed, this level forms the present recommendation for potassium in the Nigerian savanna.

2.4 Calcium

Calcium deficiency in groundnut is often reflected by unfilled pods (blindnut), the darkening of the plumule of the seed embryo and in reduced pod development. Under severe cases of deficiency, chlorosis, petiole break-down, wilting and death of the terminal bud as well as root disorganisation might result (Burkhart and Collins, 1941; Yayock and Yusuf, 1981).

The calcium content of the savanna soils of northern Nigeria, together with the amount contained in single superphosphate (19% Ca) is mostly adequate to meet the needs of groundnut. However, unfilled pods, a kin to calcium deficiency, have been reported on sites that have become exhausted through intensive and continuous cultivation (Harkness, et al., 1976). Tanimu (1982) observed that the application of calcium in the form of either gypsum, lime or both to such soils without adequate moisture does not lead to a reduction of the blindnut problem. This worker, thus concluded that water availability has an over-riding influence on pod filling than does calcium *per se*.

2.5 Magnesium

Magnesium being a component of chlorophyll molecule, its deficiency normally results in interveinal chlorosis of the terminal leaves and the stunting of groundnut plants. Under severe shortage of the element, plants completely lose their green colour and eventually die. Most savanna soils contain adequate magnesium to meet the needs of groundnut and as such it is not presently a recommended fertilizer on routine basis. But where it is necessary to apply lime to the crop, the use of the dolomitic form ($CaCO_3$ $MgCO_3$) to supply both calcium and magnesium would be an advantage (Yayock and Yusuf, 1981).

2.6 Sulphur

Sulphur is well distributed in the plant in the form of proteins, volatile components and sulphate (Burkhart and Collins, 1941). There is good indication to suggest that sulphur is required for conversion of reduced nitrogen into proteins in symbiotic nitrogen-fixing legumes.

Sulphur deficiency in groundnuts often results in reduced growth and the yellowing of leaves, similar to that of nitrogen deficiency. The terminal leaves are the first to show sulphur deficiency in contrast to nitrogen where the older leaves or the entire plants first show the deficiency (Mathur, 1967).

Probably no single element is more deficient in the soils of the savanna ecological zone of Nigeria for groundnut production than is sulphur. However, since sulphur is a constituent of single superphosphate (14% S), its deficiency is routinely corrected at the same time as that of phosphorus.

2.7 Boron

Boron has been suggested to be a co-enzyme and it stimulates nitrogen fixation by Azotobacter when present in the soil at levels up to 7 ppm (Pillai, 1967). It is also reported to confer drought resistance on crops.

Boron deficiency in groundnut causes what has been termed 'hallow-heart', a condition in which the internal portion of groundnut cotyledone is hollowed, mis-shappen and dark brown in colour.

Boron has been shown to be deficient in some savanna soils of Nigeria. For example, Balasubramanian <u>et al</u>. (1980a) reported a significant response to boron application at Samaru. But Singh and Balasubramanian (1983) working at Mokwa observed no such response. This investigation, is, therefore, hoped to ascertain the response of groundnut to boron fertilizers at both locations.

Whilst it is unfortunate that the present investigation (which commenced prior to the new formulation for phosphorus and potassium) could not be concluded before the official release this package of recommendation, its value is hardly diminished particularly in view of the need to determine the individual and interactive effects of all three nutrient elements.

Chapter 3

MATERIALS AND METHODS

3.1 Experimental Sites

Field experiments were carried out on lands that had been left fallow for several years during the 1983 and 1984 rainy season at two locations ((Samaru (11°11'N and 07°38'E) in the Northern Guinea and Mokwa (09°18'N and 05°04'E) in the Southern Guinea savanna of Nigeria)). At Samaru, the experiment was conducted in 1983 at a farmer's field, was about four kilometers from the meteorological station of the Institute of Agricultural Research, but in 1984, the study was carried out near the station. At Mokwa, the experiments were both conducted within the Research sub-Station.

The soil physico-chemical analysis for 1983 and 1984 at all the locations are presented in Appendix A. Essentially, the soil at Samaru and Mokwa were sandy loams.

3.2 Treatments and Experimental Design

The treatments consisted of three levels of phosphorus (0, 16 and 24kg P ha^{-1}), three levels of potassium (0, 20 and 40kg K ha^{-1}) and two levels of boron (0.0 and 0.5kg B ha^{-1}), thus giving a total of 18 treatment combinations which were replicated three times.

Variables were arranged in a split-plot design, with phosphorus as the main treatments and potassium and boron in the sub-plots.

Phosphorus was supplied in the form of single superphosphate (8% P) and boronated superphosphate (8% P) which also supplied boron (0.5% B). Potassium was applied in the form of muriate of potash (50% K). All three fertilizers were applied at planting.

3.3 Land Preparation and Other Management Practices

The fields were disc-ploughed, harrowed and ridged at 90cm apart. The gross sub-plots were made up of six ridges of 6m length, while the net sub-plots consisted of four ridges, each 5m long.

A standard groundnut variety recommended for each of the locations was used as follows:

Samaru:	Samaru 61
Mokwa :	Samaru 38

The experiment was planted on 17 June in 1983 and on 14 June in 1984 at Samaru. At Mokwa, plantings were on 8 June, 1983 and 11 June, 1984. The seeds were treated with Aldrex-T and placed two per hole at 25cm apart to give calculated populations of 44,000 stands ha^{-1}. Weeding was done three times at each location.

3.4 Observations

Before plants started to flower, ten plants were randomly selected from each sub-plot and tagged permanently for identification.

Using the tagged plants, the number of open flowers produced per plant were recorded on three out of the seven days of the week. At Samaru in 1984, the height and spread of each plant were recorded at two weeks interval.

At harvest, the same tagged plants were lifted carefully and the number of vegetative branches, pegs, immature and mature pods were determined.

In order to determine the yields of pod and haulm, the net sub-plots were harvested. The pods were picked and bagged in jute sacks separately and left out to dry for two weeks. The haulm from each net sub-plot was tied together in bundles and left to dry for three weeks in the field before weighing. The shelling percentage (total weight of kernels/total weight of pods x 100) and 100-kernel weight were also recorded.

3.5 Statistical Analysis

All data were statistically analysed using the method of Snedecor and Cochran (1967). Treatment means were compared using the Duncan's Multiple Range lest (Duncan, 1955).

Chapter 4

RESULTS

The rainfall started late in 1983. The distribution was generally poor, with an early cessation (Appendix 01 and 02). Apart from a slight infestation by parasitic weed (*Alectra vogelli*) at Samaru as well as a slight attack of termites *Trinervitermes* spp) at both locations during the year, no serious disease problems were encountered.

In slight contrast to the previous year, the rainfall in 1984 was good and fairly well distributed (Appendix 03 and 04). However, late cessation of the rains caused some of the kernels of 'Samaru 61' to germinate in the shell before the crop was lifted. After lifting the groundnut plants the haulms were left in the field to dry and these were slightly affected by the rains. By and large, the crop performed better in 1984 than in 1983 at both locations.

4.1 Plant Height

The change in height with time was recorded only at Samaru in 1984. The results shows that application of the different rates of either phosphorus, potassium or boron had no measurable effect (Figure 1). However, a slight and non-significant increase in height was noted in the presence of 40kg K ha^{-1} beyond the 11th week after planting. After the 13th week plants fertilized with 20kg K ha^{-1} slightly grew

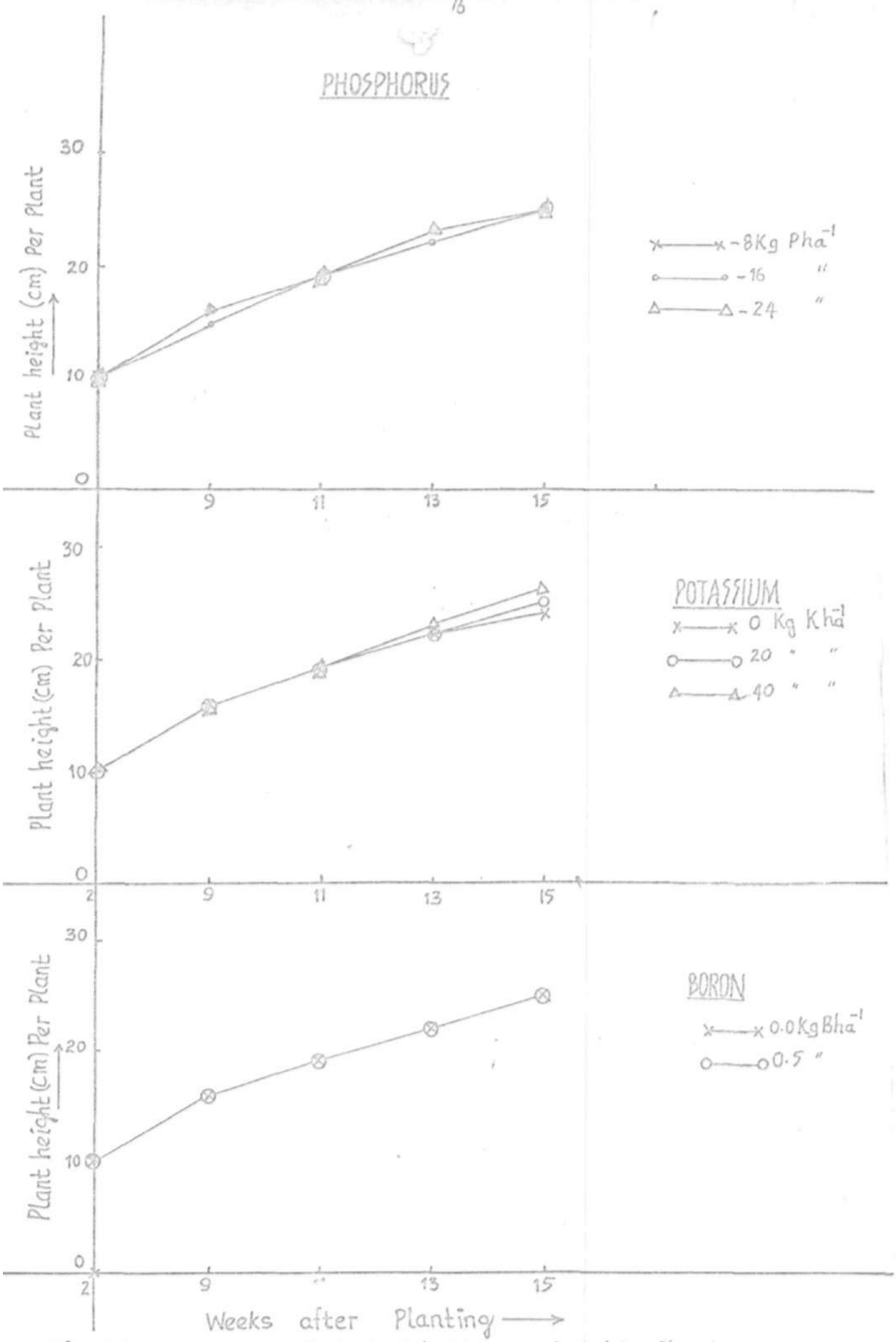

Figure I. Change in groundnut Plant height as affected by Phosphorus, Potassium and boron fertilizers at Samaru, 1984 taller than those not receiving this fertilizer.

4.2 Vegetative Branches

4.2.1 Phosphorus

The branching habit of groundnut at Samaru was not affected by fertilizer phosphate (Figure 2). Although in 1984 the presence of 16kg P ha^{-1} slightly increased the number of tertiary branches from seven to nine in comparison to 0kg P ha^{-1}. The difference was negligible.

Increasing the level of phosphorus appeared to have no effect on the number of vegetative branches at Mokwa in 1983. However, there was a slight increase in the number of secondary branches due to the application of 16kg P ha^{-1}. The presence of phosphorus beyond 0g P ha^{-1} tended to have a negative effect on the number of tertiary branches in 1984.

4.2.2 Potassium

Potassium application had no effect on the branching development at Samaru in 1983 (Figure 3). Even though the number of primary branches remained unaffected in 1984, the number of secondary branches increased from 34 in the absence of potassium to 37 and 39 as a result of application of 20 and 40kg K ha^{-1}, respectively. However, differences were not statistically significant. The same trend held true with respect to tertiary branches where the number slightly increased from seven to eight and ten, respectively.

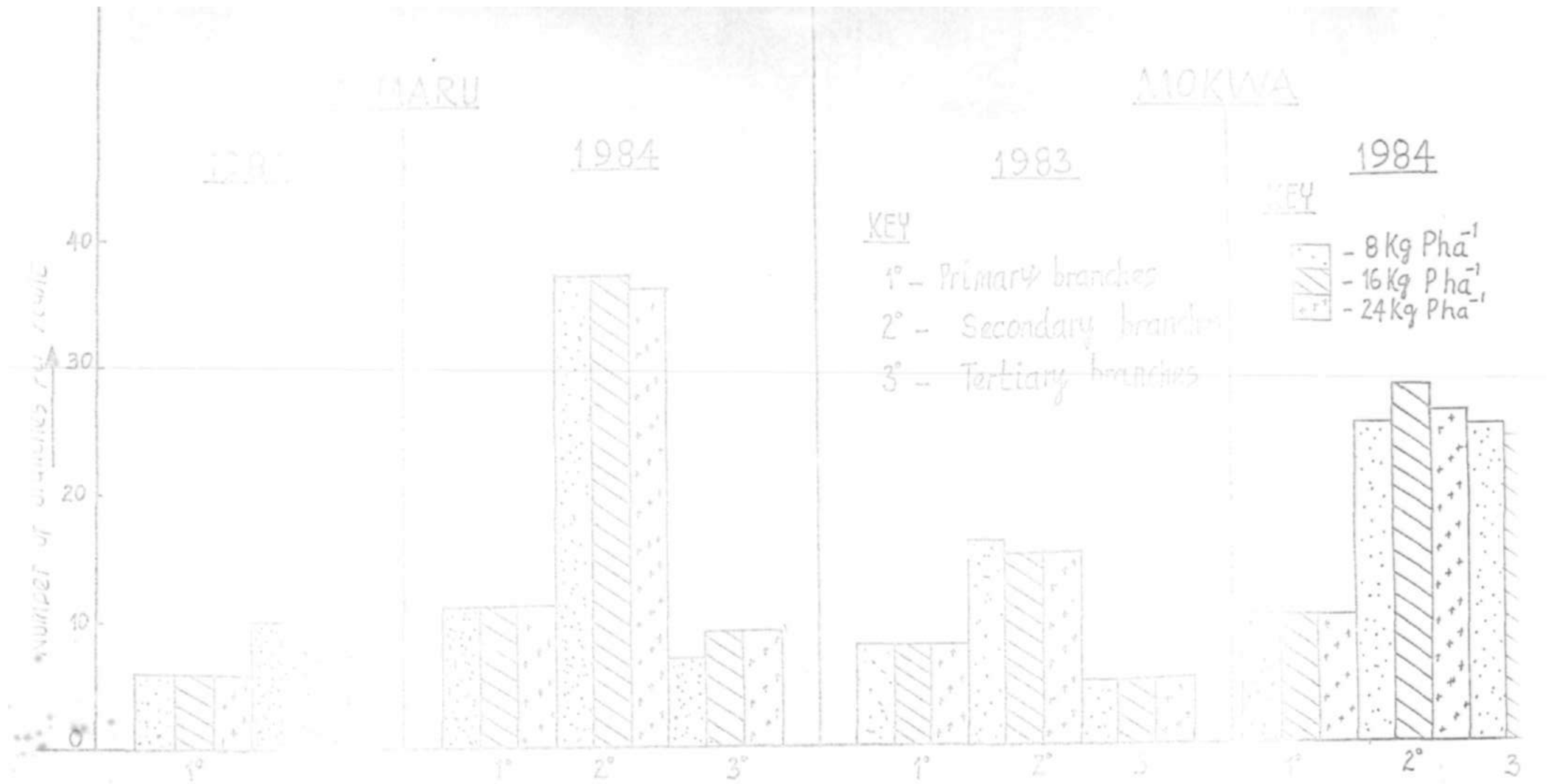

Figure ... Vegetative branches as affected by Phosphotic fertilizer

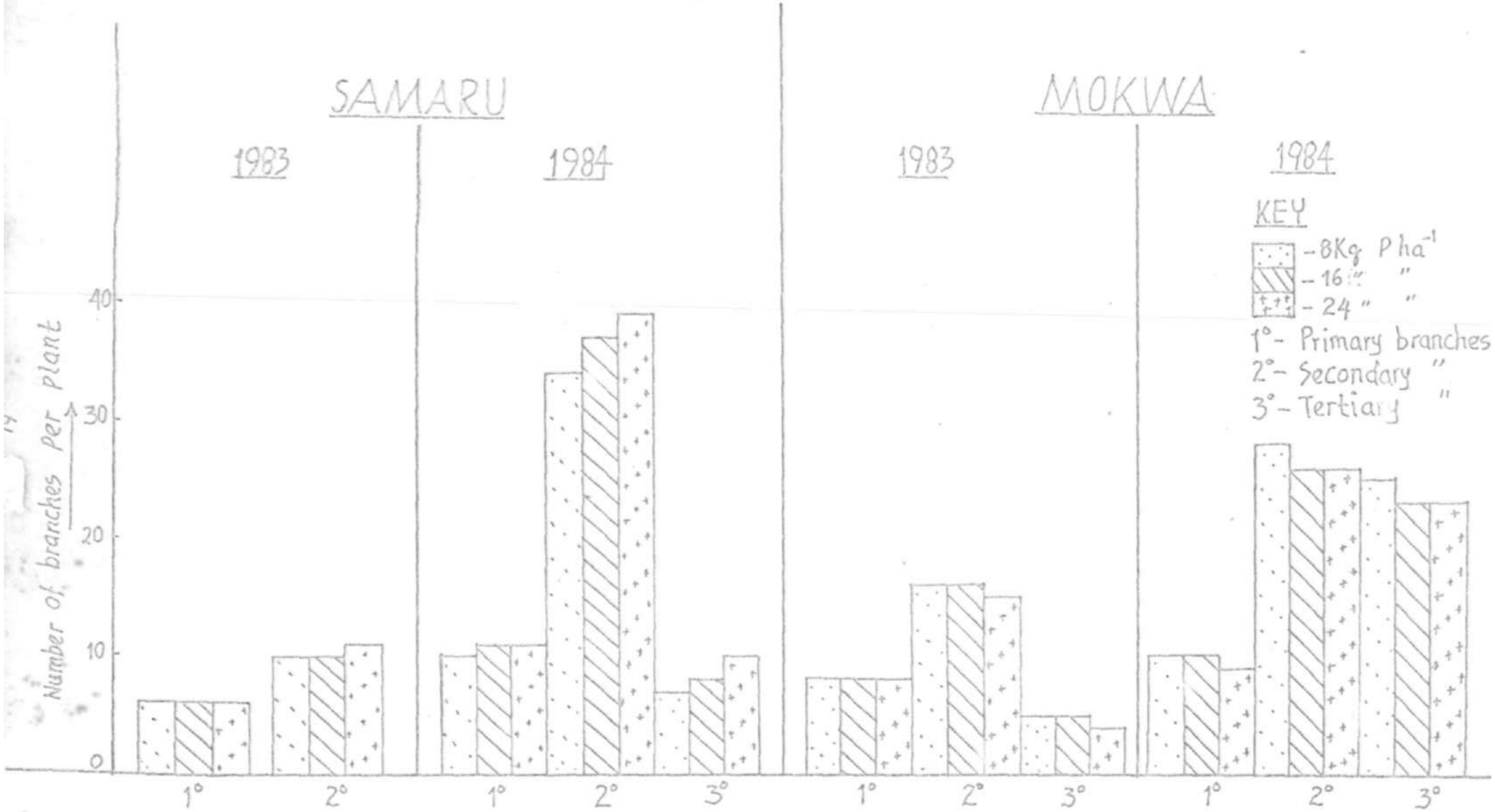

Figure 3. Vegetative branches as affected by Potassic fertilizers

In 1983 the branching development of groundnut was not affected by potash fertilizer at Mokwa. But in 1984 potassium application depressed the number of secondary and tertiary branches by 7.7 and 8.7% when 20 and 40kg K ha^{-1} were applied, respectively, but the difference was not statistically significant.

4.2.3 Boron

Boron had no detectable effect on the number of branches of groundnut (Figure 4).

4.3 Flowers

4.3.1 Phosphorus

Flower production per plant tended to be higher from 8 to 10 weeks after planting, in plants fertilized with 16kg P ha^{-1} than when 0 or 24kg P ha^{-1} were applied at Samaru in 1983 (Figure 5). But at the 11th week onwards, plants that received 24kg P ha^{-1} produced more flowers than when 0 or 16kg P ha^{-1} were supplied. In 1984, the effect of phosphorus was more pronounced during the first five (6th to 11th) weeks of the flowering period, where the rate of flower production recorded was higher when 24kg P ha^{-1} was applied than in the presence of either 0 or 16kg P ha^{-1}.

Greater numbers of flowers per plant were produced from the 6th to 8th weeks after planting at Mokwa in 1983 due to the

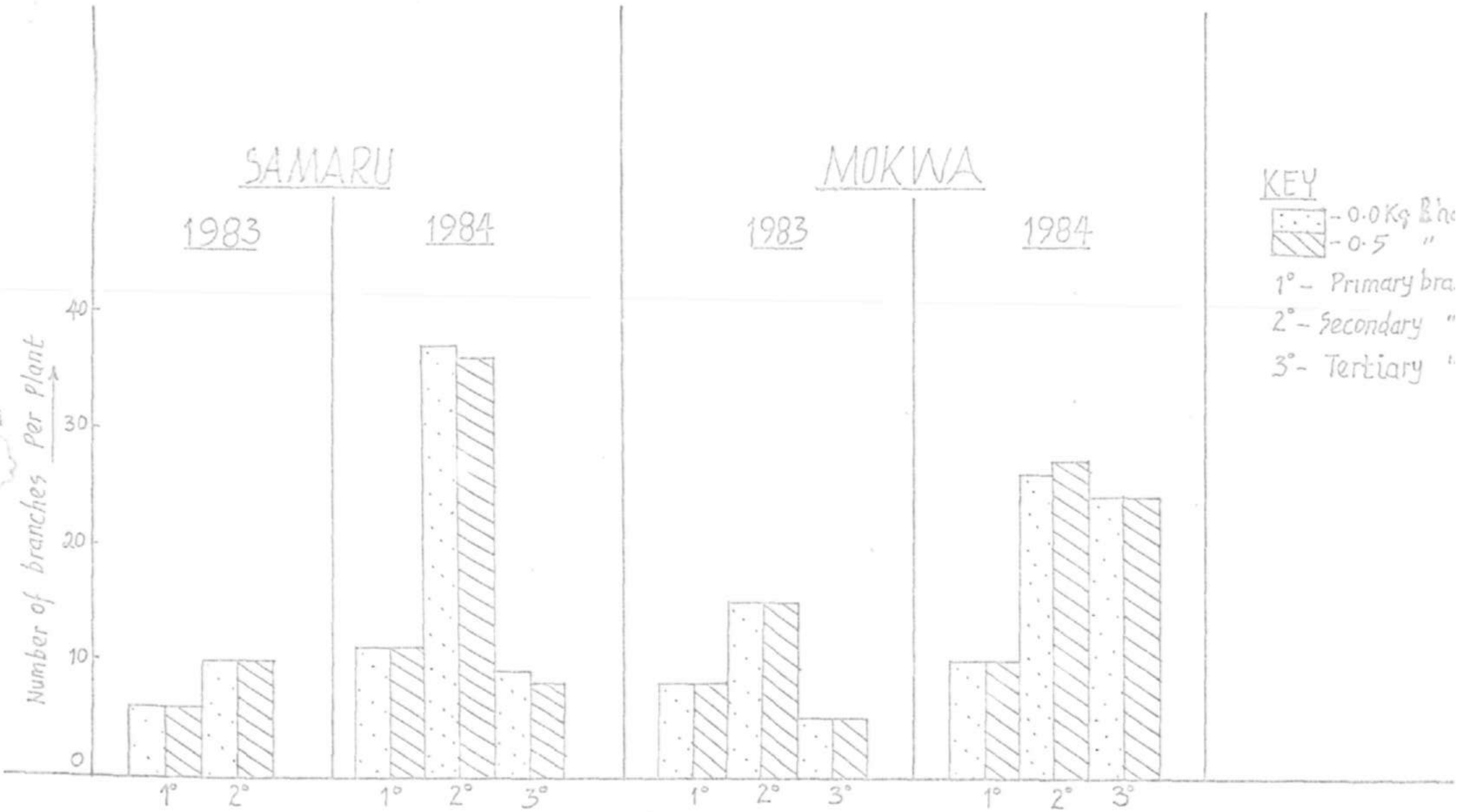

Figure 4. Vegetative branches as affected by Boron fertilizers

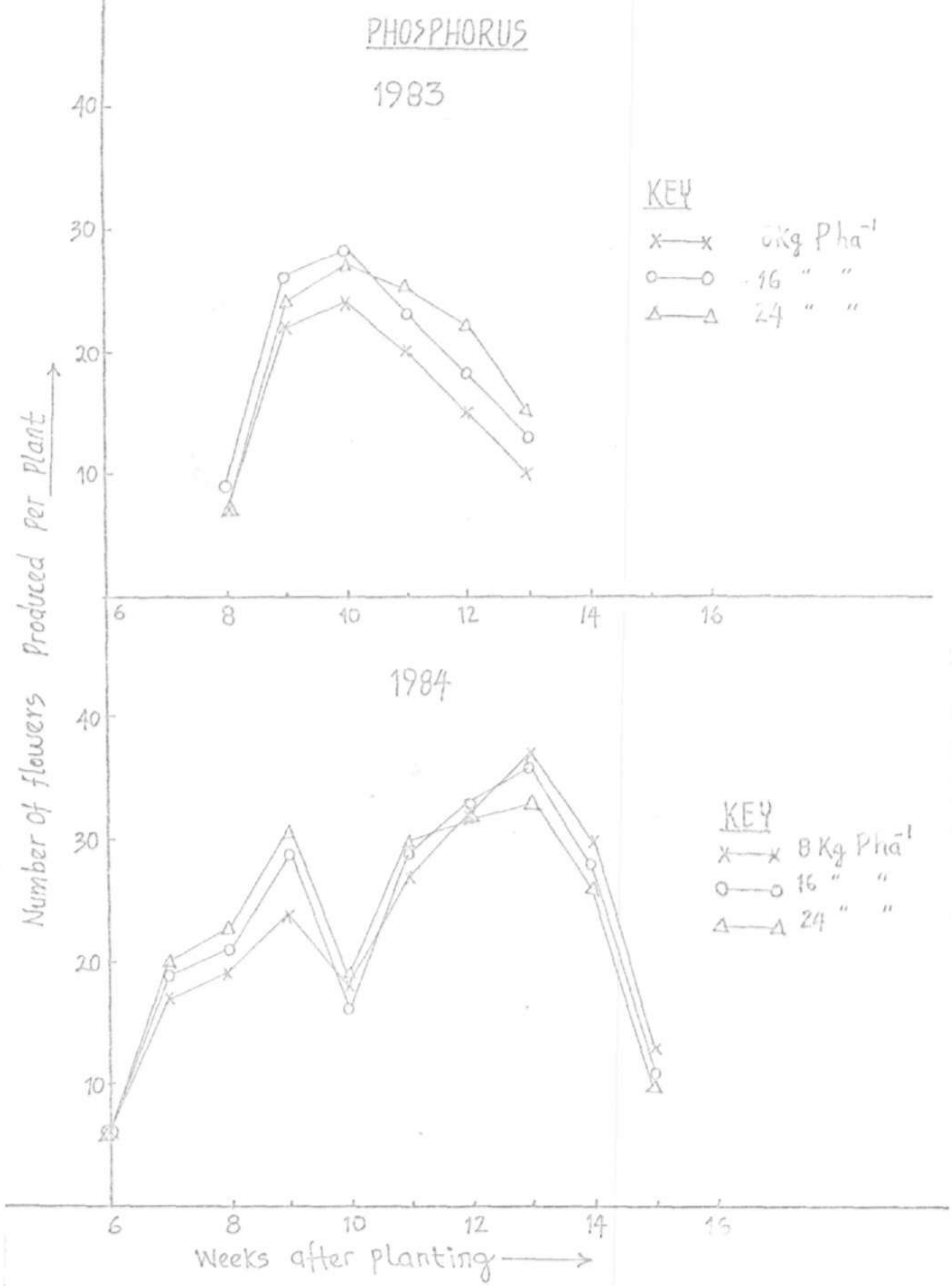

Figure 5. Flower Production as affected by Phosphoric fertilizers at Samaru

application of 16kg P ha^{-1} than when 8 or 24kg P ha^{-1} were applied (Figure 6). In 1984, fertilizer phosphate had no detectable effect on the number of flowers.

4.3.2 Potassium

The application of 20kg K ha^{-1} tended to produce more flowers than either at nil or at 40kg K ha^{-1} in 1984 at Samaru (Figure 7).

At Mokwa in 1983, increasing the level of potassium slightly increased the number of flowers produced during the 6th to 8th week after planting, but the difference was not significant statistically (Figure 8). At about 11 weeks onwards, the presence of 20kg K ha^{-1} appeared to promote the production of more flowers. In 1984, potassium had no clear effect on flower production.

4.3.3 Boron

The presence of boron had no measurable effect on the number of flowers produced per plant at Samaru in both years (Figure 9).

The use of boron resulted in increased number of flowers between the 6th to 9th weeks after planting at Mokwa in 1983. Thereafter, production fell below the level recorded in the absence of the nutrient. In 1984, the response to boron occurred after the 11th week after planting where it tended to produce more flowers than in its absence (Figure 10).

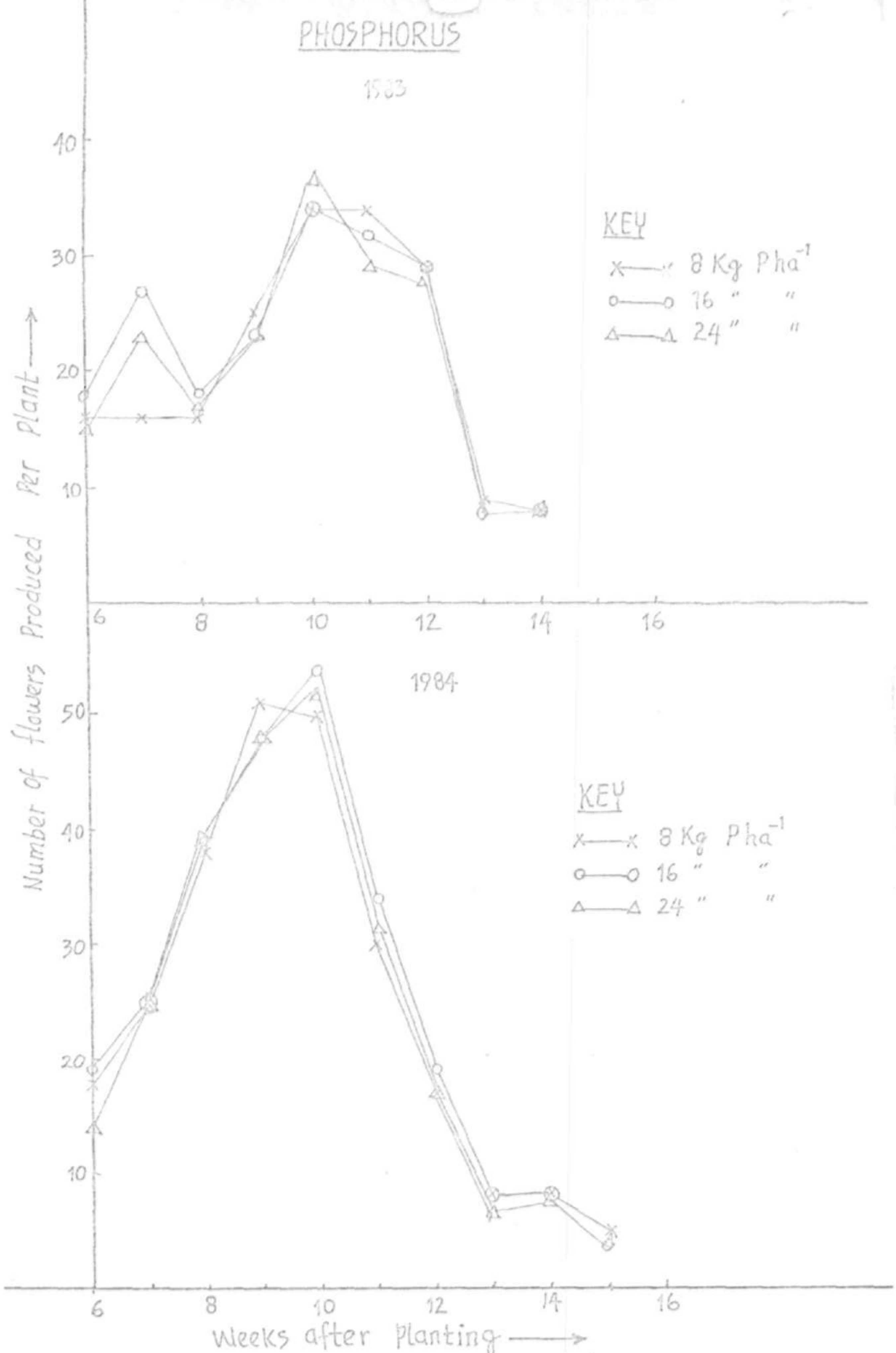

Figure 6. Flower Production as affected by Phosphoric fertilizer at Mokwa.

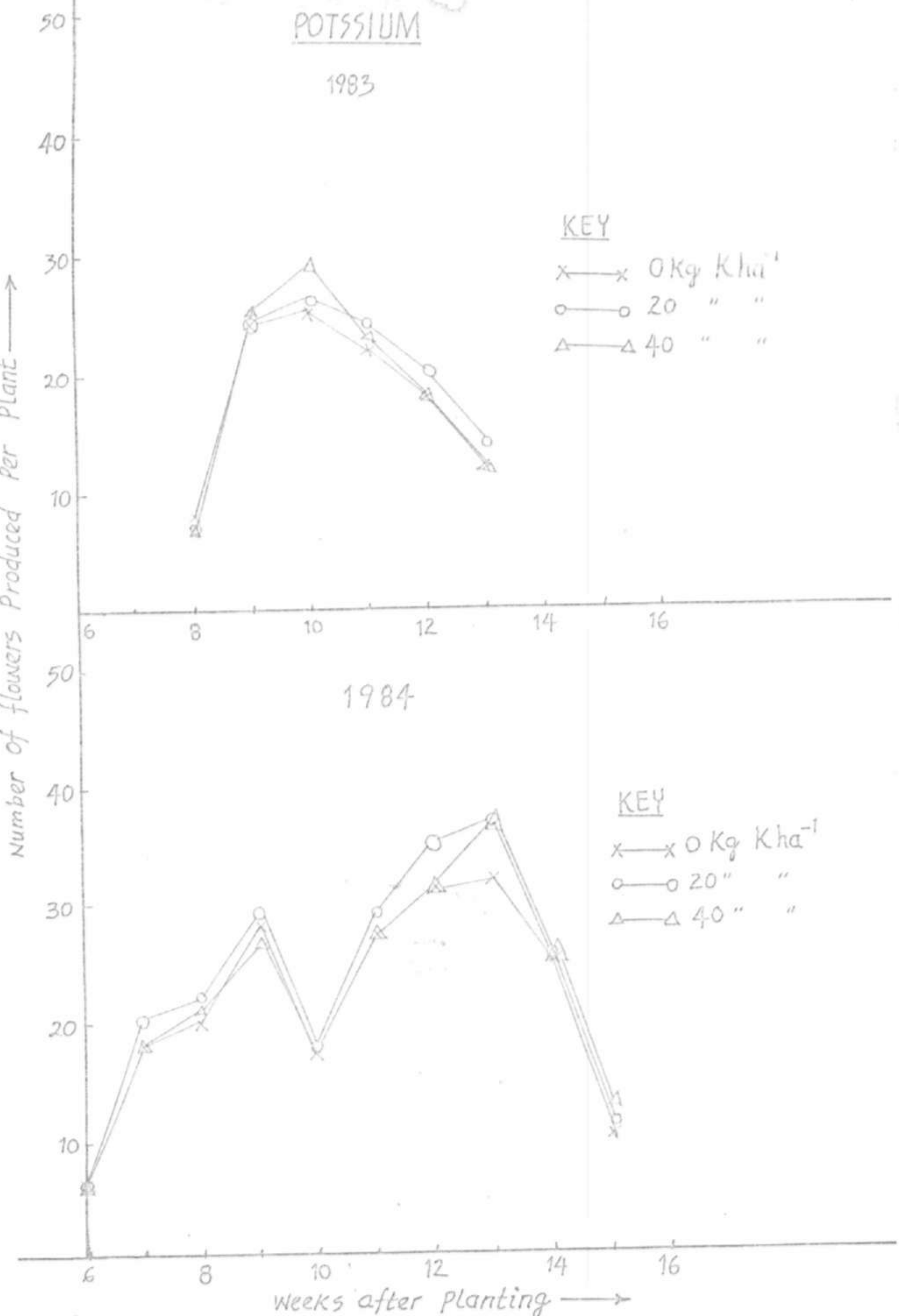

Figure 7. Flower production as affected by Potassic fertilizers at Samaru

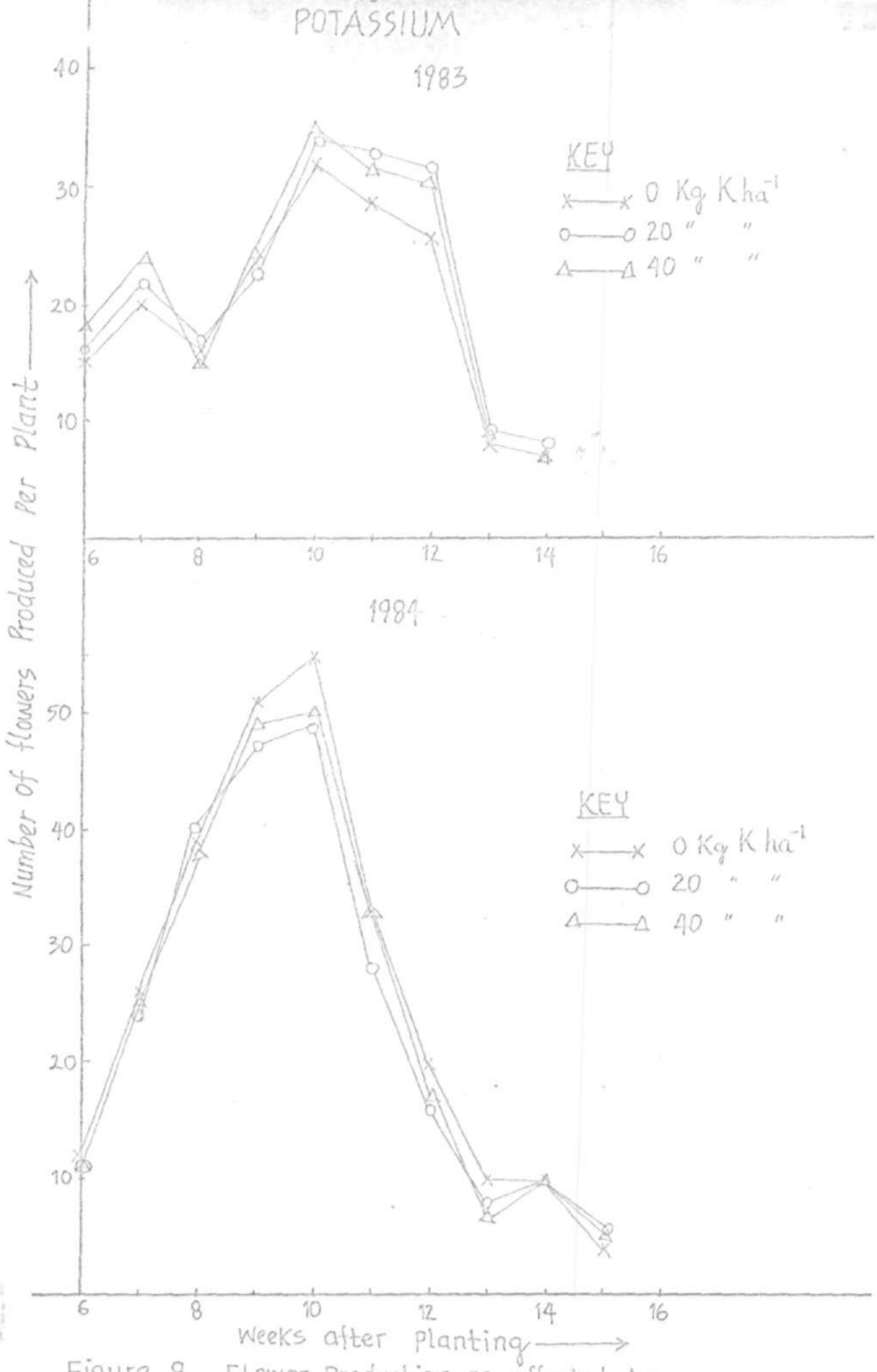

Figure 8. Flower Production as affected by Potassic fertilizers at Mokwa

BORON

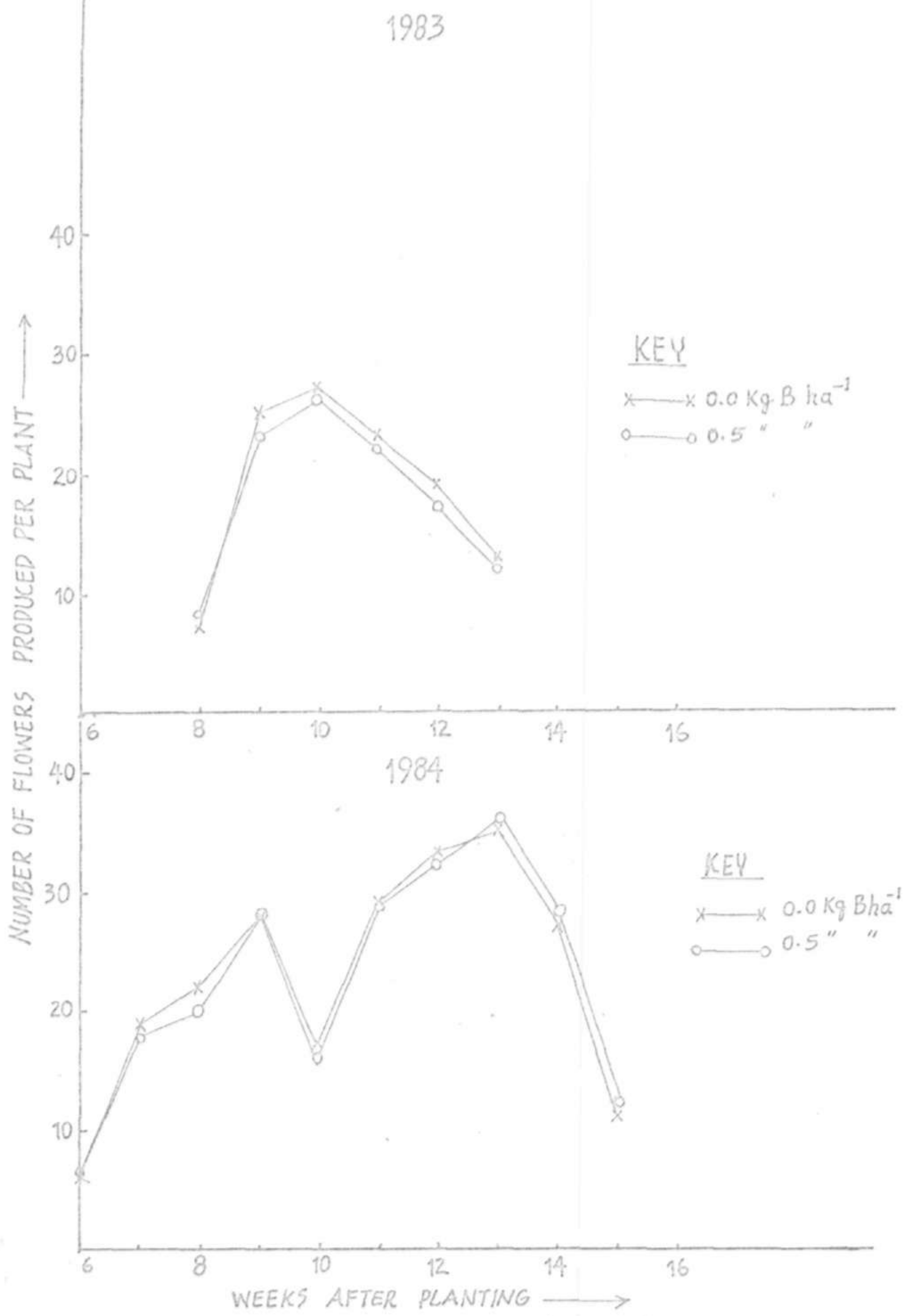

Figure 9: Flower Production as affected by boron fertilizers at Samaru

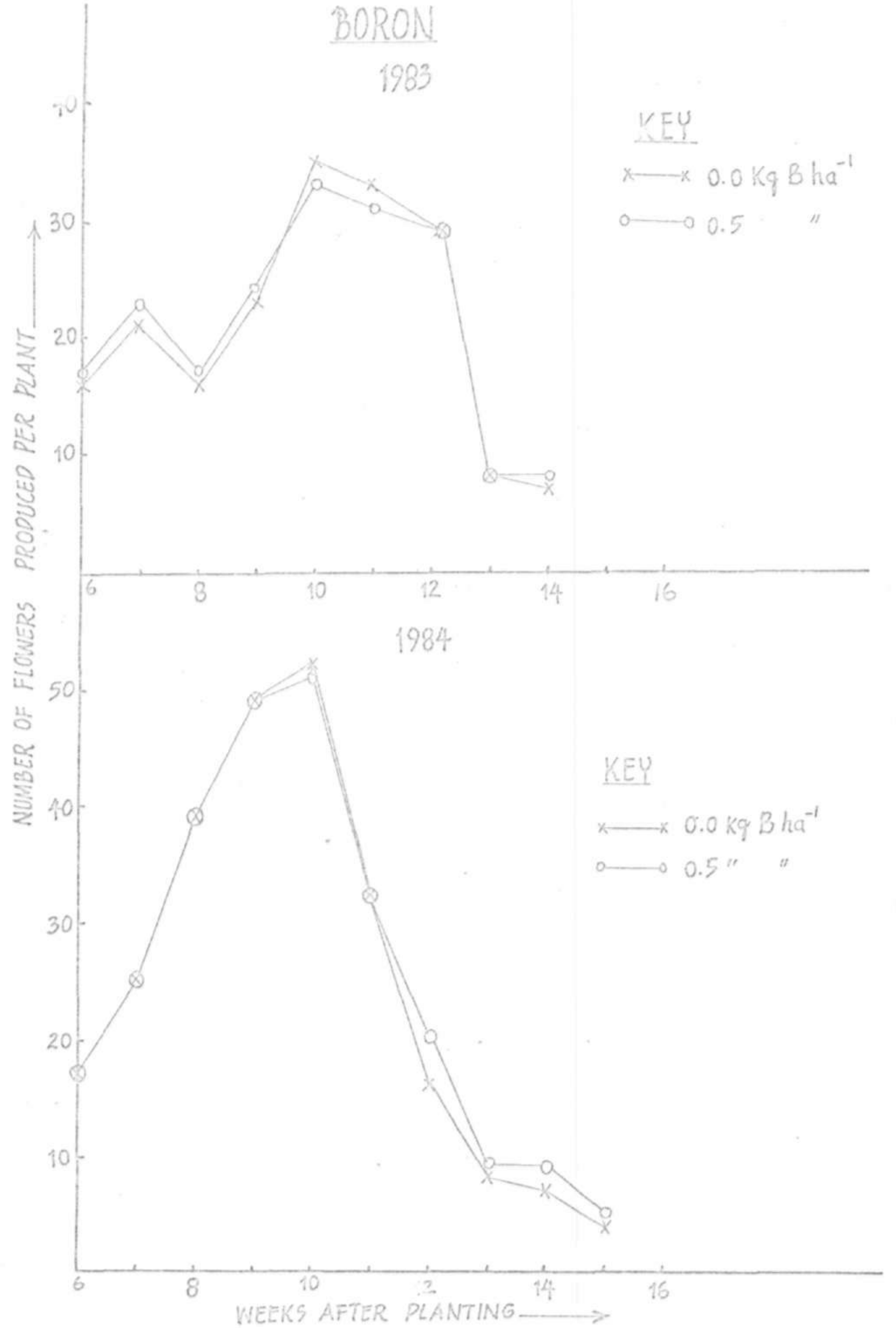

Figure 10. Flower Production as affected by Boron fertilizers at Mokwa

4.4 Pegs

4.4.1 Phosphorus

The number of pegs increased from 63.2 in the presence of 0kg P ha^{-1} to 69.8 and 64.5 when 16 and 24kg P ha^{-1} were applied, respectively, at Samaru in 1983 (Table 1). However, the result of 1984 shows that phosphorus had no detectable effect on the number of pegs.

Application of phosphatic fertilizer at Mokwa in 1983 increased the number of pegs from 73.4 when 0kg P ha^{-1} was applied to 76.9 and 74.3 due to the addition of 16 and 24kg P ha^{-1}, respectively (Table 2). The differences were negligible. In 1984 also, the response of the number of pegs to phosphorus element was non-significant.

4.4.2 Potassium

At Samaru in 1983, the use of potassium fertilizer had no measurable effect on the number of pegs (Table 1). But in 1984, the application of 20kg K ha^{-1} increased the number of pegs from 78.9 when no fertilizer potash was applied to 85.9 pegs. Higher levels of potash did not increase the number of pegs further but actually was lower than obtained with 20kg K ha^{-1}.

Greater numbers of pegs were recorded in the absence of potassium than when 20 or 40kg K ha^{-1} were supplied at Mokwa in 1983 (Table 2). However, the addition of the nutrient appeared to have a depressive effect on the number of pegs in both years.

Table 1. Effects of phosphorus, potassium and boron on the number of pegs of groundnut per plant at harvest, Samaru.

Potassium/Boron (kg ha^{-1})	1983: kg P ha^{-1} 0	16	24	Mean (K) ± 3.4	1984: kg P ha^{-1} 0	16	24	Mean (K) ± 3.2
Nil K								
Nil OB	62.7	72.3	71.3	60.1	60.0	02.2	75.0	75.6
0.5 OB	62.3	71.7	55.7	63.2 / 65.7	91.0	79.0	76.5	02.2 / 70.9
20 K								
Nil OB	74.0	53.0	67.7	64.9	06.4	91.5	63.0	05.9
0.5 OB	61.0	05.7	60.7	69.1 / 67.0	04.9	07.0	02.9	04.9 / 05.9
40 K								
Nil OB	55.3	72.0	66.0	64.4	90.5	92.0	90.0	94.0
0.5 OB	66.0	64.3	60.0	66.1 / 65.3	73.3	75.2	79.2	75.9 / 05.0
Mean (P)	63.2	69.0	64.5	(±3.0	02.5	04.6	02.7	(±4.5)
Nil OB =	65.0	(±2.7)		=	05.5	(±2.6)		
0.5 OB =	66.1			=	01.0			

Table 2. Effects of phosphorus, potassium and boron on the number of pegs of groundnut per plant at harvest, Mokwa.

Potassium/Boron ($kg\ ha^{-1}$)	1903: $kg\ P\ ha^{-1}$			Mean (K)	1904: $kg\ P\ ha^{-1}$			Mean (K)
	0	16	24	± 3.6	0	16	24	± 11.0
Nil K								
Nil B	6.7	74.0	75.3	70.0	147.3	143.5	156.2	145.0
0.5 B	75.3	09.7	72.0	79.0 / 70.5	132.2	120.2	162.0	141.1 / 145.1
20 K								
Nil B	62.3	79.7	85.7	75.9	124.9	117.0	110.5	117.5
0.5 B	69.3	75.0	75.0	73.1 / 74.5	126.3	115.5	153.5	131.7 / 124.6
40 K								
Nil B	63.7	77.7	50.3	66.6	135.7	129.6	119.5	122.3
0.5 B	05.0	65.3	79.7	76.7 / 71.6	141.7	225.4	101.3	136.1 / 142.2
Mean (P)	73.4	76.9	74.3	(±2.6)	134.7	143.2	134.0	(±9.6)

Nil B =	73.5	(±2.9)	= 131.6	(±9.0)
0.5 B =	76.3		= 143.0	

4.4.3 Boron

Boron application had no effect on the number of pegs at Samaru in 1983. Although a fewer number of pegs were recorded in the presence of boron in 1984, the difference was not statistically significant.

At Mokwa, the use of boron had negligible effect in 1983, but appeared to increase the number of pegs in 1984, but the difference was negligible (Table 2).

4.5 Unformed Pegs

4.5.1 Phosphorus

In 1983 the number of unformed pegs were unaffected by phosphorus at Samaru (Table 3). But increasing the level from 0kg P ha^{-1} to 16 and 24kg P ha^{-1} decreased the number of unformed pegs by 0.5 and 10% in 1984, respectively.

Raising the rate of fertilizer phosphate at Mokwa (Table 4) from 0kg ha^{-1} to 16 and 24kg ha^{-1} increased the number of unformed pegs from 21.1 to 26.4 and 29.3, respectively, the differences being negligible. In 1984, increasing the level of the fertilizer above 0kg ha^{-1} had no significant effect on the number of unformed pegs.

4.5.2 Potassium

The use of potash appeared to increase the number of unformed pegs at Samaru even though the difference were not

Table 3. Effects of phosphorus, potassium and boron on the number of unformed pegs of groundnut per plant at harvest, Samaru.

Potassium/Boron (kg ha^{-1})		1983: kg P ha^{-1} 8	16	24	Mean (K) ±3.0	1984: kg P ha^{-1} 8	16	24	Mean (K) ±2.5
Nil K									
Nil B		36.0	40.0	39.3	38.4	44.7	51.0	47.2	47.6
0.5 B		37.3	38.3	29.3	35.0 / 36.7	64.2	61.1	40.0	57.0 / 52.7
20 K									
Nil B		43.3	32.3	39.3	38.3	62.0	60.0	49.6	57.4
0.5 B		42.3	55.3	32.7	43.4 / 40.9	54.0	51.2	54.6	53.5 / 55.5
40 K									
Nil B		34.7	37.0	46.3	39.3	60.2	62.2	61.9	61.4
0.5 B		44.0	35.0	39.3	39.4 / 39.4	50.6	40.5	41.0	47.0 / 54.2
Mean (P)		39.8	(±39.7)	37.7	(±2.0)	56.1	55.0	50.5	(±3.5)
Nil B	=	38.7 (±2.43)			=	55.5 (±2.1)			
0.5	=	39.3			=	52.0			

Table 4. Effects of phosphorus, potassium and boron on the number of unformed pegs of groundnut per plant at harvest, Mokwa.

Potassium/Boron (kg ha^{-1})	0	16	24	Mean (K) ±3.0	0	16	24	Mean (K) ±9.1
Nil K								
Nil B	20.3	27.7	20.7	28.2	95.0	84.6	90.5	92.7
0.5 B	22.0	30.3	25.0	25.0 / 27.0	06.7	84.0	116.5	95.0 / 94.3
20 K								
Nil B	13.7	25.7	28.3	22.6	84.5	70.0	64.7	76.0
0.5 B	16.3	24.3	40.0	26.9 / 24.7	79.3	60.9	96.2	70.0 / 77.4
40 K								
Nil B	24.7	27.0	12.3	21.3	84.7	00.7	01.9	82.4
0.5 B	21.7	23.3	41.3	20.0 / 25.1	102.2	157.0	60.1	109.1 / 55.0
Mean (P)	21.1	26.4	29.3	(±3.9)	00.0	91.0	07.7	(±9.8)

Nil B	=	24.0 (±2.4)	=	83.7 (±7.4)
0.5	=	27.1	=	94.6

significant statistically (Table 3).

At Mokwa, the number of unformed pegs was reduced in the presence of 20kg K ha^{-1} (Table 4).

4.5.3 Boron

The number of unformed pegs were not affected by the addition of boron at Samaru in 1983. However, the presence of the nutrient tended to decrease the number of unformed pegs in 1984 (Table 3).

Boron appeared to increase the number of unformed pegs at Mokwa, but differences were not significant statistically (Table 4).

4.6 Immature Pods

4.6.1 Phosphorus

Raising the level of phosphorus from 8kg to 16kg ha^{-1} had virtually no effect on the number of immature pods at Samaru in 1983 (Table 5). Higher level of phosphorus (24kg P ha^{-1}) caused a non-significant increase of 8.3%. In 1984, a negligible increase in the number of immature pods was recorded from 10.2 in the presence of 8kg ha^{-1} to 11.6 and 13.0 when 16 and 24kg P ha^{-1} were supplied, respectively.

However, at Mokwa in 1983, increasing the level of phosphorus from 8kg to 16 and 24 ha^{-1} resulted in a non-significant

Table 5. Effects of phosphorus, potassium and boron on the number of immature groundnuts pods per plant at harvest, Samaru.

Potassium/Boron (kg ha^{-1})	1903: kg P ha^{-1}			Mean (K)	1904: kg P ha^{-1}			Mean (K)
	8	16	24	±0.6	0	16	24	± .7
Nil K								
Nil B	5.7	5.3	0.0	6.7	7.8	14.0	10.0	11.1
0.5 B	7.3	7.7	8.3	7.0	12.2	11.2	10.4	11.3
				7.2				11.2
20 K								
Nil B	11.3	6.0	9.0	8.8	8.0	12.5	15.2	12.2
0.5 B	5.0	4.7	5.0	4.9	11.4	9.9	11.7	11.0
				6.[illegible]				11.6
40 K								
Nil B	6.7	10.0	9.0	8.6	11.4	10.7	14.1	12.1
0.5 B	7.0	7.3	7.7	7.3	99.7	10.3	16.0	12.0
				7.9				12.1
Mean (P)	7.2	7.0	7.8	(±0.5)	10.2	11.6	13.0	(±0.9)

Nil B	=	8.0 (±0.5)	=	11.0 (±0.6)
0.5 B	=	6.7	=	11.4

decrease in the number of immature pods by 20.3 and 15.2%, respectively (Table 6). In 1984, the use of 16 and 24kg P ha^{-1} increased the number of immature pods by 31.3 and 6.9%, respectively. The differences were not significant statistically.

4.6.2 Potassium

Application of potassium had no pronounced effect on the number of immature pods at Samaru (Table 5) and Mokwa (Table 6), except in 1983 when the use of 40kg K ha^{-1} led to a negligible increase.

4.6.3 Boron

A reduction of about 16.3 and 11.6% in the number of immature pods were recorded in the presence of boron in 1983 at Samaru (Table 5) and Mokwa (Table 6), respectively. But in 1984 boron had no visible effect at Samaru, while it increased the number of immature pods by 14% at Mokwa, the differences were not significant statistically.

4.7 Mature Pods

4.7.1 Phosphorus

The number of mature pods per plant increased from 16.4 in the presence of 0kg P ha^{-1} to 23.1 and 20 when 16 and 24kg P ha^{-1} were applied, respectively, at Samaru in 1983 (Table 7), although the increase averaged 41.5 and 24.4%, respectively,

Table 6. Effects of phosphorus, potassium and boron on the number of immature groundnut pods at harvest, Mokwa.

Potassium/Boron ($kg\ ha^{-1}$)	1983: $kg\ P\ ha^{-1}$ 0	16	24	Mean (K) ±1.0	1984: $kg\ P\ ha^{-1}$ 0	16	24	Mean (K) ±2.3
Nil K								
Nil B	12.0	10.3	15.0	12.4	20.9	32.6	32.0	31.4
0.5 B	12.3	14.0	9.3	11.9 / 12.2	22.3	24.2	24.7	23.7 / 27.6
20 K								
Nil B	14.0	14.0	14.3	14.1	21.3	19.7	19.7	20.4
0.5 B	10.0	10.3	7.3	9.2 / 11.7	25.1	36.0	35.0	32.0 / 26.2
40 K								
Nil B	14.7	0.7	13.3	12.2	22.4	20.0	14.2	21.5
0.5 B	19.7	0.7	11.0	13.1 / 12.7	19.0	42.0	22.2	27.0 / 24.6
Mean (P)	13.0	11.0	11.7	($\pm$0.7)	23.2	30.4	24.0	($\pm$1.7)
Nil B =	12.9	($\pm$0.0)		=	24.4	($\pm$1.9)		
0.5 B =	11.4			=	27.0			

Table 7. Effects of phosphorus, potassium and boron on the number of mature groundnut pods per plant, Samaru.

Potassium/Boron (kg ha^{-1})	1983: kg P ha^{-1}			Mean (K)	1984: kg P ha^{-1}			Mean (K)
	0	16	24	±1.3	0	16	24	±1.0
Nil K								
Nil B	19.0	26.0	24.0	23.0	16.2	16.5	17.9	16.9
0.5 B	17.7	25.7	18.0	20.4 21.7	14.6	16.0	18.1	16.5 16.7
20 K								
Nil B	19.3	14.7	19.3	17.8	15.6	18.1	18.2	17.3
0.5 B	13.7	25.7	19.7	19.7 18.7	18.7	19.2	16.6	18.1 17.7
40 K								
Nil B	14.0	25.0	20.7	19.9	18.9	19.9	22.0	29.5
0.5 B	15.0	22.0	21.0	19.3 19.6	13.0	16.4	21.4	16.9 18.7
Mean (P)	16.4	23.2	20.4	(±1.5)	16.2	17.0	19.2	(±0.7)

Nil B = 20.2 (±1.1) = 18.3 (±0.8)

0.5 B = 19.0 = 17.2

differences were not significant statistically. In 1984, increasing the level of fertilizer phosphate to 16 and 24kg P ha^{-1} resulted in a non-significant increase of 9.9 and 18.5% in the number of mature pods.

Application of 0kg P ha^{-1} at Mokwa produced 41.5 and 22.8 mature pods in 1983 and 1984, respectively. The use of higher levels of phosphorus tended to have no effect on the number of mature pods (Table 8).

4.7.2 Potassium

Greater numbers of mature pods per plant were produced in the absence of potash than when 20 and 40kg K ha^{-1} were applied at Samaru in 1983 (Table 7), although differences were negligible statistically. In 1984, potassium slightly increased the number of mature pods from 16.7 in unfertilized plots to 17.7 and 18.7 when 20 and 40 kg K ha^{-1} were applied, respectively. At Mokwa, potassium appeared to reduce the number of pods in both years (Table 8).

4.7.3 Boron

Application of boron had no measurable effect on the number of mature pods at Samaru. But tended to decrease the number at Mokwa.

Table 8. Effects of phosphorus, potassium and boron on the number of mature groundnut pods per plant, Mokwa.

Potassium/Boron ($kg\ ha^{-1}$)	1983: $kg\ P\ ha^{-1}$ 0	16	24	Mean (K) ± 2.3	1984: $kg\ P\ ha^{-1}$ 0	16	24	Mean (K) ± 1.5
Nil K								
Nil B	44.3	36.0	50.0	43.4	23.4	26.3	24.9	24.9
0.5 B	41.7	45.3	37.7	41.6 / 42.5	23.2	20.0	21.7	21.6 / 23.3
20 K								
Nil B	41.3	43.7	43.0	42.7	19.0	18.6	25.7	21.1
0.5 B	36.3	40.3	27.7	34.8 / 38.7	21.8	18.4	22.3	20.8 / 21.0
40 K								
Nil B	41.0	42.0	32.7	38.6	20.6	20.9	23.3	24.3
0.5 B	44.3	33.3	37.3	38.3 / 38.5	20.5	26.3	11.0	19.3 / 21.0
Mean (P)	41.5	40.1	38.1	(± 1.0)	22.0	21.8	21.5	(± 1.5)
Nil B =	41.6 (± 1.0)			=	23.4 (± 1.3)			
0.5 B =	38.2				20.6			

4.0 Shelling Percentage

4.0.1 Phosphorus

In 1983, increasing the level of phosphorus from 0kg to 16kg P ha^{-1} slightly increased the shelling percentage at Samaru (Table 9). In 1984, it increased from 70.2% in the presence of 0kg P ha^{-1} to 72.0 and 71.2% when 16 and 24kg P ha^{-1} were added, respectively. The differences were not significant statistically.

Additional phosphorus beyond the 0kg P ha^{-1} had no detectable effect on the shelling percentage at Mokwa in 1984, though in 1983, highest level increased the percentage (Table 10).

4.0.2 Potassium

In the absence of potash fertilizer the shelling percentage recorded in 1983 was 63.0 which was increased to 64.7 and 65.5% in the presence of 20 and 40kg K ha^{-1}, respectively. The differences were not significant statistically. Potash had no effect on the shelling percentage at Samaru in 1984.

The use of potash at Mokwa appeared to decrease the shelling percentage in 1983. But no detectable effect was recorded in 1984.

4.0.3 Boron

Boron application at Samaru raised the shelling percentage slightly in 1983, but had neutral effect in 1984.

Table 9. Effects of phosphorus, potassium and boron on the shelling percentage (%) of groundnut at Samaru.

Potassium/Boron (kg ha^{-1})	1983: kg P ha^{-1}			Mean (K)	1984: kg P ha^{-1}			Mean (K)
	8	16	24	±0.5	8	16	24	±0.5
Nil K								
Nil B	60.0	63.7	57.7	60.7	71.2	72.4	72.9	72.2
0.5 B	65.9	66.1	63.7	65.2	70.1	73.5	71.4	71.6
				63.0				71.9
20 K								
Nil B	64.8	63.5	66.3	64.9	69.9	71.7	72.4	71.3
0.5 B	63.2	68.9	61.3	64.5	70.1	71.4	71.9	71.2
				64.7				71.2
40 K								
Nil B	67.0	66.7	63.7	65.8	69.1	71.3	69.0	70.1
0.5 B	65.7	64.0	65.7	65.1	70.9	71.6	60.9	70.8
				65.5				70.3
Mean (P)	64.6	65.5	63.1	(±0.4)	70.2	72.0	71.2	(±0.7

Nil B = 63.0 (±0.4) = 71.2 (±0.4)

0.5 B = 64.9 = 71.1

Table 10. Effects of phosphorus, potassium and boron on the shelling percentage (%) of groundnut at Mokwa.

Potassium/Boron ($kg\ ha^{-1}$)	1983: $kg\ P\ ha^{-1}$ 8	16	24	Mean (K) ±2.5	1984: $kg\ P\ ha^{-1}$ 8	16	24	Mean (K) ±0.6
Nil K								
Nil B	60.5	71.2	77.0	72.2	65.0	65.7	60.2	66.3
0.5 B	70.0	79.9	75.8	75.2 73.7	65.5	66.2	65.6	65.8 66.0
20 K								
Nil B	79.5	65.3	73.0	72.6	65.3	69.0	66.2	66.0
0.5 B	56.0	73.0	80.0	70.1 71.4	64.5	66.6	66.3	65.8 66.3
40 K								
Nil B	70.0	75.2	69.3	74.1	67.7	66.9	67.5	67.1
0.5 B	67.0	51.2	70.0	65.7 69.9	65.0	66.4	65.5	65.9 66.5
Mean (P)	69.0	69.4	75.7	(±2.1)	65.6	66.7	66.6	(±0.9)

Nil B = 73.0 (±2.0)   = 66.7 (±0.5)

0.5 B = 70.3   = 65.0

At Mokwa, boron tended to decrease the shelling percentage, although differences were negligible statistically.

4.9 100-Kernel Weight

4.9.1 Phosphorus

No change in kernel weight was recorded at Samaru by increasing the level of fertilizer phosphate from 8kg to 16 or 24kg ha^{-1} in 1983 (Table 11). In 1984, increasing the level of phosphorus from 8kg to 16kg ha^{-1} produced a non-significant increase (4.0%) in weight.

Increasing the level of phosphorus fertilizer above 8kg P ha^{-1} had an effect on the kernel weight at Mokwa in 1983 (Table 12). A slight increase from 48.1g in the presence of 8kg P ha^{-1} to 49.3 and 49.8g when 16kg and 24kg P ha^{-1} were applied, respectively, 1984.

4.9.2 Potassium

Potassium fertilizer was found to have no visible effect on the kernel weight of groundnut, except at Mokwa in 1983 where the addition of 29kg K ha^{-1} tended to increase the weight.

4.9.3 Boron

Application of boron had no defectable effect on the kernel weight.

Table 11. Effects of phosphorus, potassium and boron on the 100-kernel weight (g) of groundnut at Samaru.

Potassium/Boron (kg ha^{-1})	1903: kg P ha^{-1}			Mean (K)	1904: kg P ha^{-1}			Mean (K)
	0	16	24	±0.5	0	16	24	±0.5
Nil K								
Nil B	34.7	31.2	34.5	33.5	41.3	40.9	42.0	41.4
0.5 B	35.0	30.5	33.0	35.5	37.9	40.4	43.2	40.5
				34.5				41.0
20 B								
Nil B	34.3	30.4	33.1	35.3	30.1	40.0	40.9	39.9
0.5 B	32.3	35.0	32.5	33.5	39.5	41.1	42.4	41.0
				34.4				40.5
40 K								
Nil B	37.0	33.1	34.0	35.2	40.2	42.0	30.2	40.4
0.5 B	35.9	33.6	34.6	34.7	41.1	41.6	42.1	41.6
				35.0				41.0
Mean (P)	35.2	35.1	33.0	(±1.1)	39.7	41.3	41.5	(±0.5)

Nil B	=	34.7 (±0.4)	=	40.6 (±0.4)
0.5 B	=	34.6	=	41.0

Table 12. Effects of phosphorus, potassium and boron on the 100-kernel weights (g) of groundnut at Mokwa.

Potassium/Boron ($kg\ ha^{-1}$)	1983: $kg\ P\ ha^{-1}$			Mean (K)	1984: $kg\ P\ ha^{-1}$			Mean (K)
	0	16	24	±1.4	0	16	24	±1.3
Nil K								
Nil B	62.4	59.0	60.1	60.0	40.0	46.6	50.7	40.7
0.5 B	55.7	54.5	56.0	55.7 50.2	40.1	51.1	51.4	50.2 49.5
20 K								
Nil B	62.5	56.0	50.0	59.4	40.4	53.0	52.3	51.2
0.5 B	62.0	61.4	65.7	63.0 61.2	49.4	44.0	40.5	47.6 49.4
40 K								
Nil B	54.5	59.0	57.7	57.3	46.5	51.1	49.1	40.9
0.5 B	63.5	60.7	57.5	60.6 50.9	47.7	49.3	46.3	47.0 40.4
Mean (P)	60.1	50.0	59.4	(±1.9)	40.1	49.3	49.0	(±0.9)
Nil B =	55.2	(±1.1)		=	49.6	(±1.0)		
0.5 B =	59.7			=	40.5			

4.10 Pod Yield

4.10.1 Phosphorus

Pod yield increased from 953kg ha^{-1} in plots of fertilized with 0kg P ha^{-1} to 1263kg and 1046kg ha^{-1} at Samaru in 1983, when 16kg and 24kg P ha^{-1} were applied, respectively, (Table 13). Even though these increases averaged 32.5 and 9.7%, respectively, differences were not statistically significant. Increasing the level of phosphorus in 1984 from 0kg P ha^{-1} to 16kg and 24kg P ha^{-1} similarly resulted in non-significant pod increases, averaging 13.5 and 22.5%, respectively.

Pod yield was increased (by 6.8%) from 1493kg ha^{-1} in the presence of 0kg P ha^{-1} to 1594kg in plots supplied with 16kg P ha^{-1} at Mokwa in 1983 (Table 14). Beyond this level of phosphorus, there was a reduction in yield (by 9.4%). Raising the level of phosphorus from 0kg P ha^{-1} to and 24kg P ha^{-1} in 1984 slightly increased pod yield by 3.5 and 2.9%, respectively.

4.10.2 Potassium

There was a negligible effect of potassium on yield beyond the 1111kg and 1220kg pods ha^{-1} recorded in the absence of the nutrient in 1983 and 1984, respectively, at Samaru.

Compared with a yield of 1453kg ha^{-1} recorded in the absence of potash fertilizer at Mokwa in 1983, the use of 20kg K ha^{-1}, caused a non-significant yield increase by 6.6%. A higher level of potash did not lead to a further increase in

Table 13. Effects of phosphorus, potassium and boron on the pod yield (kg ha^{-1}) of groundnut at Samaru.

Potassium/Boron (kg ha^{-1})	1903: kg P ha^{-1} 0	16	24	Mean (K) $\pm$69.7	1904: kg P ha^{-1} 0	16	24	Mean (K) $\pm$37.1
Nil K								
Nil B	995	1270	1013	1092	1150	1241	1369	1256
0.5 B	1176	1339	075	1130 1111	915	1263	1377	1105 1220
20 K								
Nil B	1246	1039	1021	1102	1002	1116	1120	1005
0.4 B	640	1264	976	963 1032	1171	1193	1305	1250 1166
40 K								
Nil B	009	1265	1321	1250	1172	1193	1216	1194
0.5 B	766	1403	1071	1000 1119	1015	1271	1305	1224 1209
Mean (P)	953	1263	1046	($\pm$147.7)	1072	1213	1310	($\pm$55.5)

Nil B = 1117 ($\pm$56.9) = 1177 ($\pm$30.3)

0.5 B = 1050 = 1219

Table 14. Effects of phosphorus, potassium and boron on the pod yield (kg ha^{-1}) of groundnut at Mokwa.

Potassium/Boron	1903: kg P ha^{-1}			Mean (K)	1984: kg P ha^{-1}			Mean (K)
(kg ha^{-1})	0	16	24	($\pm$00.7)	0	16	24	$\pm$67.5
Nil K								
Nil B	1549	1381	1402	1470	1518	1570	1059	1652
0.5 B	1616	1381	1313	1437 / 1453	1936	1625	1966	1042 / 1747
20 K								
Nil B	1347	1052	1448	1549	1572	2101	1507	1727
0.5 B	1604	1503	1301	1549 / 1549	1814	1659	1713	1729 / 1728
40 K								
Nil B	1145	1414	1212	1257	1737	2119	2053	1970
0.5 B	1616	1953	1200	1616 / 1437	1954	1019	1736	1836 / 1903
Mean (P)	1493	1594	1352	($\pm$87.0)	1755	1017	1006	($\pm$30.5)

Nil B	=	1425 ($\pm$72.4)	=	1703 ($\pm$55.1)
0.5 B	=	1534	=	1002

pod yield. But in 1984, application of 20kg K ha^{-1} had no pronounced effect, although raising the level to 40kg K ha^{-1} increased the yield by 8.9%. Differences were, however, not statistically significant.

4.10.3 Boron

The use of boron at Samaru tended to depress yield in 1983, although its effect was statistically negligible. While in 1984, it slightly increased the pod yield from 1177kg to 1219kg ha^{-1}, thus averaging 3.6%.

Application of boron increased pod production by 7.6% at Mokwa in 1983, although this difference was statistically insignificant. In 1984, boron had no detectable effect on pod yield.

4.11 Haulm Yield

4.11.1 Phosphorus

The application of 8kg P ha^{-1} at Samaru in 1983 resulted in the production of 1722kg of haulm; higher levels of phosphorus tended to reduce haulm production. Haulm yield was increased (by 10%) in 1984 from 3535kg ha^{-1} in the presence of 8kg P ha^{-1} to 3902kg at 16kg P ha^{-1} (Table 15). Application of 24kg P ha^{-1} appeared to have a depressive effect on yield.

The use of 8kg P ha^{-1} resulted in the production of 3070kg of haulm at Mokwa in 1983 (Table 16). Higher levels of

Table 15. Effects of phosphorus, potassium and boron on the haulm yield (kg ha^{-1}) of groundnut at Samaru.

Potassium/Boron (kg ha^{-1})	1903: kg P ha^{-1} 0	16	24	Mean (K) ±00.8	1904: kg P ha^{-1} 0	16	24	Mean (K) ±139.3
Nil K								
Nil B	1671	1973	1705	1009	3195	4734	3600	3070
0.5 B	1411	1485	1203	1366 / 1588	3102	3090	3306	3409 / 3679
20 K								
Nil B	1606	1252	2175	1670	3535	3740	3292	3523
0.5 B	1960	1641	1551	1720 / 1699	3403	3340	3222	3351 / 3437
40 K								
Nil B	1752	2002	1463	1739	3936	3922	3346	3735
0.5 B	1925	1975	1673	1050 / 1790	3076	3771	3170	3600 / 3672
Mean (P)	1702	1721	1642	(±100.3)	3535	3902	3351	(±240.3)
Nil B =	1742	(±66.1)		=	3709	(±113.0)		
0.5 B =	1640			=	3403			

Table 16. Effects of phosphorus, potassium and boron on the haulm yield (kg ha^{-1}) of groundnut at Mokwa.

Potassium/Boron (kg ha^{-1})	1903: kg P ha^{-1} 0	16	24	Mean (K) $\pm$99.6	1904: kg P ha^{-1} 0	16	24	Mean (K) $\pm$126.3
Nil K								
Nil B	3232	2795	2929	2905	2740	2020	2601	2721
0.5 B	2963	2626	2155	2581 / 2703	3200	3303	2509	3140 / 2930
20 K								
Nil B	2062	3367	2525	2910	3007	2626	3159	2924
0.5 B	2963	2963	3030	2905 / 2952	3204	3479	2000	3190 / 3057
40 K								
Nil B	3333	2096	2593	2941	3205	2061	2710	2925
0.5 B	3064	3603	2525	3064 / 3002	2909	3639	3442	3330 / 3120
Mean (P)	3070	3042	2626	($\pm$150.0	3059	3110	2930	($\pm$103.2)

Nil B = 2940 ($\pm$81.3) = 2857 ($\pm$103.2)

0.5 B = 2077 = 3220

L.S.D. (at P = 0.05) = NS = 299.4

phosphorus decreased the yield. In 1984, the yield was increased from 3059kg in plots supplied with 8kg P ha^{-1} to 3110kg in the presence of 16kg P ha^{-1}.

4.11.2 Potassium

Potassium fertilizer increased the yield of haulm from 1588kg ha^{-1} in the absence of the nutrient to 1699kg and 1790kg ha^{-1} when 20 and 40kg K ha^{-1} were applied, respectively, at Samaru in 1983. Differences were not statistically significant. In 1984, fertilizer potash did not seem to have any effect on haulm production.

At Mokwa, potassium increased the yield from 2783kg in the control treatment to 2952kg and 3002kg when 20 and 40kg K ha^{-1} were applied, respectively. Also in 1984, the yield was raised from 2930kg in the absence of K to 3057kg and 3128kg ha^{-1} when 20 and 40kg K ha^{-1} were applied, respectively. However, the differences were not statistically significant.

4.11.3 Boron

The use of boron tended to have a depressive effect on haulm production. However, at Mokwa in 1984 the haulm yield increased significantly by 12.7% by the application of this micro-nutrient.

Chapter 5

DISCUSSION

5.1 Effect of Phosphorus

Vegetative growth was not affected by increasing the level of phosphorus from 0kg P ha^{-1} to either 16 or 24kg P ha^{-1} in 1983. This may be explained on the basis of rainfall during the crop growth period (Appendix D1-D4). The fertilizers applied could not be effectively utilized for growth and development of the crop due to inadequate and unfavourable distribution of rainfall. But the more favourable rainfall in 1984 tended to support more vegetative growth. Although increasing the level of the fertilizer from 0kg P ha^{-1} to 16kg P ha^{-1} slightly increased the number of vegetative branches in that year, differences were not significant statistically. The same trend was recorded for haulm yield, wheree the highest yields were observed when 8 and 16kg P ha^{-1} were applied in 1983 and 1984, respectively. Availability of nutrient elements in 1984 as a result of more favourable rainfall may be the reason for higher level of response in that year.

Flower production per plant appeared to increase with increasing levels of phosphorus. The less favourable rainfall in 1983 might be the likely factor that set limit to high flower production at 16kg P ha^{-1}. Because in 1984, when rainfall was more fairly distributed, the use of 24kg P ha^{-1} produced the highest number of flowers at Samaru. However, at Mokwa flower production increased with increasing levels of phosphorus, up to 16kg P ha^{-1}.

Pod yield increased by 32.5 and 9.7% when 16 and 24kg P ha^{-1} were applied, respectively, in 1983 at Samaru. Similarly, increasing the level of phosphorus in the following year from 8 to 16 and 24kg P ha^{-1} resulted in pod increases averaging 13.5 and 22.5%, respectively. This result agrees with the report of Balasubramanian et al. (1980a) and (1981), and Singh (1984) to the effect that application of 16 to 24kg P ha^{-1} increased the yield of groundnut significantly. At Mokwa, pod yield increased with increasing levels of phosphorus, up to 16kg P ha^{-1} when 6.8 and 3.5% increase in pod yield were recorded when fertilizer levels were raised from 8 to 16kg P ha^{-1} in 1983 and 1984, respectively.

5.2 Effect of Potassium

Pod yield, 100-kernel weight and number of mature pods were not affected by the application of potassium at Samaru. This finding contrasts the report of Balasubramanian et al. (1981) and Singh (1984) to the effect that the response of groundnut to applied potassium was significant. The lack of response to potassium at Samaru may be explained largely by the presence of high level of available soil potassium at the experimental sites which had previously been left fallow for several years (Appendix A). However, at Mokwa the use of potassium increased both the pod and haulm yields, although differences were not significant. The reason for this response may be attributed to the low level of exchangeable potassium in the Mokwa soils.

5.3 Effect of Boron

Boron was found to have no measurable effect on pod and haulm yields. Other yield attributes were also not significantly affected by this fertilizer at Samaru. The results apparently contradict the report of Balasubramanian *et al.* (1980b) who indicated that groundnut crop gave significantly higher yields with boron in fields that have been under continuous cultivation. However, this investigation was conducted on land that had previously been left fallow for several years. This may infer that the lack of response to boron may be due to its high initial content in the soil. The use of boron at Mokwa increased the haulm yield significantly, but pod yield increased only slightly.

Chapter 6

SUMMARY AND CONCLUSION

Groundnut pod yield increased by an average of 23 and 16% when 16 and 24kg P ha^{-1} were applied at Samaru. Other yield attributes such as mature pods per plant, shelling percentage and 100-kernel weight were only slightly increased with increasing levels of phosphorus, up to 24kg P ha^{-1}. At Mokwa, pod yield increased with increasing levels of of phosphorus up to 16kg P ha^{-1}. Application of this fertilizer above 8kg P ha^{-1} did not have a positive effect on other yield components.

The use of potassium and boron fertilizers on sites that had been left fallow for several years had no apparent advantage on the production of groundnut at Samaru. However, there is good indication to suggest that application of potassium increase pod and haulm yields at Mokwa.

In conclusion, the investigation has shown that application of 16kg P ha^{-1} alone at Samaru is sufficient to increase groundnut yield on a fallow land, while at Mokwa the use of 16kg P + 20kg K ha^{-1} is necessary for increased yields.

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Appendix A. The physico-chemical properties of the soils sampled from the experimental sites at Samaru and Mokwa in 1983 and 1984.

Soil Characteristics		Samaru		Mokwa	
		1983	1984	1983	1984
pH	($CaCl_2$)	5.1	5.4	5.5	5.9
	(Water)	6.2	6.1	5.1	5.4
Exchangeable Cations (Meq/100g)					
	Ca	1.996	1.021	0.923	1.447
	Mg	0.790	0.732	0.200	0.307
	K	0.120	0.202	0.051	0.007
	Na	0.091	0.007	0.003	0.100
C.E.C. (Meq/100g)		5.8	6.1	8.5	7.4
Org. Carbon %		0.82	0.88	0.49	0.50
Total N (%) unit		0.0323	0.0444	0.0197	0.0230
Available P (ppm)		4.305	4.63	4.37	10.31
Mechanical Composition (%)					
	Clay	8	10	6	4
	Silt	39	42	11	13
	Sand	53	48	83	83

Appendix 8.1 : Daily rainfall at Samaru, 1983 (mm)

Date	May	June	July	Aug.	Sept.
1	-	-	-	2.1	2.0
2	-	9.0	11.0	35.0	-
3	-	4.0	Ta	14.5	-
4	-	-	9.7	1.1	1.1
5	-	-	6.6	0.0	21.0
6	-	-	-	-	11.3
7	-	-	0.9	27.0	-
8	-	0.2	0.3	0.5	16.3
9	-	-	-	-	-
10	-	-	10.2	17.0	-
Total	-	14.0	46.7	90.0	51.7
11	3.5	7.4	0.0	-	2.6
12	16.4	-	-	-	-
13	-	-	0.3	-	7.4
14	16.9	-	-	-	-
15	-	6.6	-	-	12.0
16	-	-	6.0	-	10.0
17	0.1	-	-	-	-
18	-	-	-	40.4	4.6
19	-	-	-	21.0	1.6
20	17.2	-	1.2	14.6	-
Total	54.1	14.0	0.3	87.0	30.2
21	-	-	-	-	-
22	-	-	10.4	0.5	-
23	2.0	-	-	6.2	-
24	3.0	24.5	-	-	-
25	-	1.0	0.5	26.3	3.5
26	1.3	-	-	24.7	-
27	-	-	0.3	-	-
28	0.9	17.1	27.0	19.2	-
29	-	3.7	6.3	-	-
30	-	-	-	-	-
31	4.0	-	-	-	-
Total	19.2	46.3	52.5	76.9	3.5
Grand Total for the month	74.3	74.3	107.5	259.7	93.4

Total for the year = 600.2

Appendix D.2 : Daily Rainfall at Samaru, 1984 (mm)

Date	Mar	Apr	May	June	July	Aug.	Sept.	Oct.
1	-	-	-	3.7	8.1	-	16.0	-
2	-	-	-	-	Tr	-	-	49.0
3	-	-	-	-	-	-	-	15.0
4	-	-	-	-	7.0	-	31.5	-
5	-	-	39.0	2.2	3.8	23.3	0.7	-
6	-	-	-	0.4	-	-	13.5	-
7	-	-	-	-	-	-	-	-
8	-	-	18.0	-	-	49.0	-	50.5
9	5.2	-	2.6	-	-	-	-	9.2
10	-	-	-	-	-	7.8	-	0.8
Total	5.2	-	59.6	6.3	18.9	80.1	61.7	124.5
11	-	-	-	-	17.9	-	-	-
12	-	-	-	18.3	0.9	-	-	-
13	-	-	-	19.8	13.0	-	-	-
14	-	-	-	-	20.1	-	-	-
15	-	-	-	-	-	-	-	-
16	-	-	-	-	-	8.1	-	-
17	-	-	25.0	-	-	10.0	27.0	53.0
18	-	-	-	-	-	-	-	-
19	-	-	-	0.4	7.2	14.4	-	-
20	-	Tr	-	-	7.4	-	0.6	-
Total	-	-	25	38.5	66.5	32.5	27.6	53.0
21	-	1.3	-	-	-	12.6	33.6	-
22	-	-	-	10.0	4.2	-	-	-
23	-	3.9	-	0.2	0.4	-	-	-
24	-	0.2	-	-	23.5	5.7	-	-
25	-	-	5.7	-	1.2	0.6	-	-
26	-	14.0	3.5	0.4	-	Tr	25.5	-
27	-	-	-	-	6.5	-	3.0	-
28	-	1.7	4.6	-	18.6	-	2.1	-
29	-	-	-	Tr	-	14.5	35.5	-
30	-	9.0	0.5	-	34.0	12.1	-	-
31	-	-	-	-	-	-	-	-
Total	-	30.1	14.3	10.6	88.4	32.9	99.7	-
Grand Toral for the month	5.2	30.1	98.9	55.4	173.8	158.1	189.0	177.5

Total for the year = 888.0

Appendix B.3 : Daily Rainfall at Mokwa, 1983 (mm).

Date	Apr.	May	June	July	Aug.	Sept.	Oct.
1	-	-	8.2	-	-	-	-
2	-	-	-	-	-	-	-
3	-	-	28.5	7.3	13.9	6.4	-
4	-	-	-	-	-	-	15.2
5	-	-	-	4.3	1.6	17.6	-
6	-	-	-	4.0	20.4	2.4	-
7	-	10.1	-	-	-	-	-
8	-	-	1.6	5.6	17.4	16.7	-
9	-	0.4	-	-	0.4	-	-
10	1.2	5.6	-	2.3	-	0.4	-
Total	1.2	16.1	38.3	23.6	53.7	43.5	15.2
11	1.3	-	27.4	1.8	-	-	-
12	-	16.5	-	-	-	9.6	-
13	-	12.8	26.4	-	-	-	-
14	-	-	-	1.3	-	-	-
15	-	20.0	-	-	-	-	-
16	-	5.3	1.2	-	-	9.4	-
17	-	-	-	0.7	-	30.6	-
18	-	-	-	-	-	-	-
19	-	14.8	12.6	-	28.4	4.5	-
20	-	-	0.5	-	14.2	-	-
Total	2.5	75.0	68.1	6.7	42.6	54.5	-
21	-	14.0	-	-	-	-	-
22	-	9.2	-	-	-	22.5	-
23	-	-	-	-	-	-	-
24	-	7.5	-	-	-	36.0	-
25	-	-	7.7	-	7.4	32.8	-
26	-	-	-	-	-	30.0	-
27	-	22.3	-	-	-	-	-
28	8.3	-	-	-	-	0.3	-
29	-	-	5.3	-	1.4	17.5	-
30	-	-	-	-	-	0.2	-
31	-	-	-	-	-	-	-
Total	8.3	53.0	13.0	-	8.8	139.3	-
Grand total for the month	10.8	139.5	119.4	27.3	105.1	236.9	15.2

Total for the year = 654.2

Appendix B.4 : Daily rainfall at Mokwa, 1984 (mm).

Date	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
1	-	-	14.6	13.6	4.8	-	-	-
2	-	-	-	-	12.1	-	8.3	-
3	-	-	33.9	-	-	-	7.7	29.5
4	-	-	-	-	-	-	0.4	-
5	-	-	-	-	-	-	-	-
6	-	-	30.0	13.4	-	0.3	-	-
7	-	-	-	-	-	7.7	-	12.4
8	-	-	11.5	-	-	-	-	-
9	-	-	1.9	1.2	58.3	-	-	-
10	-	-	-	-	0.2	-	-	40.7
Total	-	-	91.9	28.2	75.4	8.0	66.4	82.6
11	-	6.2	6.2	0.5	5.2	-	3.2	-
12	-	-	-	-	-	-	54.0	45.6
13	-	-	-	-	-	3.6	-	-
14	-	-	-	-	25.3	-	41.2	1.5
15	-	9.6	-	-	18.0	-	-	-
16	-	-	-	-	-	-	8.7	-
17	-	0.3	-	-	-	12.2	-	-
18	-	-	-	17.6	-	-	-	-
19	64.2	-	3.5	-	9.7	-	-	23.0
Total	64.2	16.1	9.7	18.1	58.2	15.8	107.7	70.9
20	-	-	-	-	6.7	-	-	11.9
21	-	-	-	15.2	-	3.2	9.6	-
22	-	-	-	-	18.5	-	-	-
23	-	8.2	-	-	-	54.4	-	-
24	-	-	28.3	-	-	-	-	-
25	-	-	-	0.9	-	19.6	-	-
26	-	-	-	-	3.7	1.4	-	-
27	-	-	-	-	15.0	9.3	2.3	-
28	-	3.8	-	-	-	1.2	-	-
29	-	3.2	-	-	-	34.2	-	-
30	-	-	-	20.6	-	17.2	4.4	-
31	-	-	-	-	2.4	-	-	-
Total	-	15.2	28.3	36.7	46.3	140.9	16.3	11.9
Grand total for the month	64.2	31.3	129.9	83.0	179.9	164.3	129.6	165.4

Total for the year = 947.6 mm.

Appendix C. SHORT BIOGRAPHY Mohammed Gidado HASSAN

Name	:	Mohammed Gidado HASSAN
Date of Birth	:	7th August, 1957.
Business Address	:	Department of Agronomy, Ahmadu Bello University, Zaria.
Home Address	:	No. 2Kakar Street, Tudun Wada, Katsina, Kaduna State.

Previous Qualifications

Institution Attended	From	To	Cert./Dip./Degree
Gidado Primary School, Katsina.	1964	1970	First School Leaving Certificate.
Government College, Kaduna	1971	1975	W.A.S.C.
College of Arts, Science and Technology, Zaria.	1975	1977	I.J.M.B.
Ahmadu Bello University, Zaria.	1977	1981	B.Sc. (Agric.)

Post(s) Held since the Award of First Degree

Organisation	From	To	Position
Ahmadu Bello University, Zaria.	1982	Date	Graduate Assistant.

Year of Admission for Postgraduate Studies: 1983

Admission Number: M.Sc./Agric./4270/1982-83.