EFFECT OF POTASSIUM NUTRITION ON THE YIELD AND QUALITY OF CASSAVA (*Manihot esculenta* Crantz)

BY

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THESIS
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1983

DECLARATION

I hereby declare that this thesis entitled "Effect of potassium nutrition on the yield and quality of cassava (*Manihot esculenta* Crantz)" is a bonafide record of research work done by me during the course of my study for the Ph.D. degree and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellayani,
7th September, 1985.

(P. GOPALAKRISHNAN NAIR)

CERTIFICATE

Certified that this thesis entitled "Effect of potassium nutrition on the yield and quality of cassava (*Manihot esculenta* Crantz)" is a record of research work done independently by Shri. P. GOPALAKRISHNAN NAIR under my guidance and supervision and that it has not previously formed the basis for any degree, fellowship or associateship to him.

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INTRODUCTION

Cassava (<u>Manihot esculenta</u> Crantz) is a tuber crop cultivated throughout the tropics where it is estimated to serve as a staple for over 200 million people (Asher *et al.*, 1980). World cassava production in 1983 is forecast to be 120 million tonnes of tubers corresponding to 40 million tonnes of grain equivalents (FAO, 1983). It is the most popular subsidiary food crop of the middle and low income group of people in Kerala State. Cassava is grown over an area of 2.48 lakh hectares in Kerala, which accounts for about 80 per cent of the total area of the crop in India. The total production is only 37.5 lakh tonnes (Directorate of Economics and Statistics, 1982), which works out to an average yield of 15.12 t/ha as compared to 60 t/ha in a fertile alluvial soil of Cauca Valley of Colombia (CIAT, 1978). With the use of high yielding varieties and judicious application of organic manures and chemical fertilizers, coupled with better agro-techniques, this crop yields about 25-30 t/ha of tubers (CTCRI, 1980) under Kerala conditions. Hence, it is high time that the yield of cassava in our country is enhanced in view of the higher demand for starch in the industrial sector and as a subsidiary food crop for the lower income populations.

Potassium, through its role in the synthesis and translocation of carbohydrates is of considerable importance for tuber crops especially cassava. It is well known that root and tuber crops feed considerably on potassium. Cassava requires a considerable amount of potassium which is made use of in the synthesis and translocation of starch. Until recently the mineral nutrition of cassava had not been the subject of intensive or detailed scientific investigation.

Crop improvement programmes by breeding and management especially in the case of tuber crops has necessarily to be related to quality since it is known to be affected considerably by both the variety and nutrients available or added to the soil. The potassium recommended at present for cassava are based only on the economic yield. A critical assessment of quality in relation to levels and time of potash nutrition has to be made to suggest modifications, if any, for potassic fertilization in order to improve the edible quality and other technological problems in relation to the use of cassava.

Accurate diagnosis is essential if nutritional problems are to be dealt with effectively. Visual symptoms of nutrient deficiencies play an important role in the diagnosis made under field conditions.

Considering the above aspects the present study was initiated with the following objectives.

(1) To find out the optimum level of potassium for economic yield and tubers of good quality.

(2) To find out the optimum time of application of potassium to cassava.

(3) To find the critical concentration of potassium in cassava leaf.

(4) To see whether the quality of cassava improved by the application of potassium, and

(5) To find out the relation between yield and yield components and starch and starch characters.

Review of literature

REVIEW OF LITERATURE

1. Nutrient removal by cassava

Cassava produces comparatively higher yields per unit area and hence removes considerably greater amounts of nutrients from the soil than many other crops. The amount of nutrients removed per hectare by a crop is considered as an indicator of the rate of exhaustion of the soil and of the significant role played by a particular nutrient in plant production. According to Prevot and Ollagnier (1958) among tropical crops, cassava extracts the largest amount of potassium from the soil. But Hongspan (1962) considered that one ton of food produced by cassava depleted the soil nutrient reserves less than maize, sugarcane, banana and cabbage. According to Kanwar (1974) among the nutrient exhausting crops grown in tropical situations, cassava takes the third rank, the first and second being banana and sugarcane respectively (table 1).

Table 1. Nutrient removal of different crops

Crops	Yield	Nutrients removed (kg/ha)		
		N	P_2O_5	K_2O
1. Rice	3178 kg	125.6	74.0	160.5
2. Cassava	..	139.0	116.6	654.7
3. Groundnut	1016 kg	269.0	43.7	207.4
4. Coconut	5600 nuts	64.1	28.0	134.5
5. Sugarcane	100 t	403.6	175.0	684.0

6.	Banana	1200 plants	448.4	448.4	1682.0
7.	Jute	1 t	80.7	39.5	140.0
8.	Tea	1 t	102.0	10.0	44.8
9.	Tobacco	1962 kg	141.2	29.0	280.0
10.	Rubber	1000 kg latex	6.7	3.36	9.6

According to Kanapathy (1974), on a per crop basis, cassava extracts more nutrients than most of the other crops (table 2).

Table 2. Removal of N, P & K by four tropical crops (kg/ha)

Crop production, t/ha)		N	P_2O_5	K_2O
Cassava	(20.9)	97.5	42.2	131.2
Oil palm	(20.4)	68.4	11.1	94.2
Rubber	(1.13)	10.1	2.2	12.3
Maize	(3.4)	91.9	23.2	77.3

But earlier estimates by Romsine (1940) had found that cassava ranks first among the tropical crops as far as nutrient removal is concerned (table 3).

Table 3. Plant nutrient removal by tropical crops

Crops	Yield	Nutrients removed (kg/ha)		
		N	P_2O_5	K_2O
1. Rice	3178 kg grain & 3178 kg straw	125.6	67.3	188.3
2. Wheat	2906 kg grain & 2724 kg straw	208.3	60.5	181.6
3. Cassava	50 t tubers & 25 t tops	623.5	153.2	739.9
4. Potatoes	25 t tubers & vines	282.5	127.8	396.0
5. Sweet potatoes	144 t tubers & vines	115.5	44.8	235.4
6. Sugarcane	100 t stalks, tops & trash	405.6	129.0	467.5
7. Cotton	681 kg lint & 1222 kg seed & stalks	201.8	70.6	141.3
8. Coconuts	3600 nuts & 12 fronds (per annum)	84.1	28.0	134.5
9. Sugarbeets	30 t roots & 16 t tops	206.0	44.8	616.6
10. Tobacco	1816 kg leaf, 1634 kg stalks, tops & suckers	269.0	33.6	296.0

The following citations from literature gives the amount of nutrients removed by cassava, as estimated in different tropical countries of the world.

Greenstreet and Lambourne (1933) reported that cassava with root yields of 28-30 t/ha consumed 114-209 kg of N, 25-37 kg of P_2O_5 and 240-335 kg of K_2O.

According to Nijholt (1935) a crop of cassava yielding 52.7 t/ha, removes 0.72 kg N, 1.18 kg P_2O_5 and 6.1 kg K_2O/ha per tonne of harvested tuber whereas the total plant removes 2.50 kg N, 2.09 kg P_2O_5 and 10.09 kg K_2O per ton of tuber.

Jacques (1937) reported a crop removal of 0.7 kg N, 4.7 kg P_2O_5 and 9.2 kg K_2O by 1 tonne of cassava roots.

Mejia Franco (1946) estimated nutrient removal of cassava roots producing 26 t/ha as 1.49 kg N, 1.09 kg P_2O_5 and 2.39 kg K_2O per ton of tuber.

Cours (1953) in Madagascar, reported that an yield of 50 t/ha of tubers and 25 t/ha aerial parts by cassava removed from the soil the following amount of nutrients.

	N	P_2O_5	K_2O (kg/ha, removed/ton)
Roots	3.06	0.76	4.44
Total plant	5.06	1.25	6.84

Dufournet and Guerin (1957) determined the following nutrient removal by a cassava crop yielding 42 t/ha.

	N	P_2O_5	K_2O (kg/ha per ton)
Roots	3.64	0.89	5.28
Total plant	6.02	1.49	7.14

Jones (1959) in his monograph "Manioc in Africa" presents some estimates of nutrients (N, P and K) required to produce 1000 calories of food in the form of cassava, rice, sorghum and banana. For cassava the number of grams of plant nutrients N, P and K required for producing 1000 calories are 2.3, 0.9 and 2.3 respectively.

Potaschemes in 1961, based on some field experiments conducted in Kerala State, reported that an yield of 10 tonnes of raw tapioca tuber removed 60.9 kg N, 50.4 kg P_2O_5 and 257.6 kg K_2O/ha.

Cours and Fritz (1961) found that for a 40 t/ha crop of cassava the nutrient removal was 85 kg N, 62 kg P_2O_5 and 200 kg K_2O/ha.

According to Jacoby (1965) the average nutrient extraction for a 60 t/ha crop of cassava is 120 kg N, 104 kg P_2O_5 and 584 kg K_2O/ha. This was based on field experiments conducted in Brazil, Costa Rica, Nigeria, Vietnam and Malaysia. Jacob and Uexkull (1966) also reported approximately similar levels of nutrient removal.

Dias (1966) reported that a 25 t/ha of root yield in cassava resulted in the removal of 2.2 kg N, 0.42 kg P_2O_5 and 1.9 kg K_2O/ha per ton of harvested tuber.

De Geus (1967) in "Fertilizer Guide for tropical and sub-tropical farming" reported a removal of 60 kg N, 111.5 kg P_2O_5 and 309.6 kg K_2O/ha from the soils of Kerala and 65 kg N, 130.3 kg P_2O_5 and 536 kg K_2O/ha from the soils of Madagascar, for cassava.

Kanapathy and Keat (1970), in a peat soil at Kuala Lampur, Malaysia, reported the following crop removal for cassava.

	N	P_2O_5	K_2O (kg/ha per ton)
Roots	2.02	0.96	3.62
Total plant	6.28	4.21	7.84

Arraudeau (1971) found that a 40 t/ha crop of cassava removed 273 kg N, 104 kg P_2O_5 and 267 kg K_2O/ha.

Dulong (1971) in Madagascar reported that a 40 t/ha of cassava removed 1.85 kg N, 0.83 kg P_2O_5 and 2.18 kg K_2O/ha per ton of harvested tuber.

According to Obigbesan (1977) there was a crop removal of 5.92 kg N, 2.0 kg P_2O_5 and 11.9 kg K_2O/ha per ton of harvested tuber, for a 40 t/ha yield of cassava in Western Nigeria.

Osiegle (1977) reported a crop removal of 174 kg N, 46.8 kg P_2O_5 and 150 kg K_2O/ha for a cassava yield of 43 t/ha.

Sittibusaya and Kurmarohita (1978) from field experiments on cassava in Thailand, found the following crop removal for a 31 t/ha crop:

	N	P_2O_5	K_2O (kg/ha per ton)
Roots	1.00	1.36	1.82
Total plant	2.35	2.30	2.78

Hendershott *et al.* (1972) gave the average nutrient removal by 14 month old cassava producing 59 tonnes of tubers, as 106 kg N, 104.8 kg P_2O_5 and 560 kg K_2O/ha.

Howeler (1978) reported approximate nutrient removal values of cassava calculated from available data in the literature. NPK removal, calculated in a systematic way from dry matter and nutrient concentration in various plant parts was presented by Asher *et al.* (1980).

Approximate amounts of nutrients (kg) required to produce a 30 t/ha crop of cassava

Nutrients	Total amounts required for a 30 t/ha root yield (kg)
Nitrogen	164
Phosphorus	31 (69, P_2O_5)
Potassium	200 (240, K_2O)

Obigbesan and Fritz (1980) reported a nutrient uptake of cassava in Nigeria for a drymatter yield of 12.4 t roots and 10.5 t tops/ha as 145, 98 and 569 kg N, P_2O_5 and K_2O/ha respectively.

Studies conducted at CTCRI, Trivandrum (1978) have also shown that between 100-200 kg N, 15-22 kg P_2O_5 and 140-160 kg K (168-192 kg K_2O) were removed by a 30 t/ha cassava crop.

2. N:K ratio

Cours (1953) from field experiments in Madagascar reported that N and K should be applied in the ratio 1:1

for cassava.

Pillai (1969) studying the response of N, P & K in conjunction with Ca on variety M4 found that potash @ 200 kg K_2O/ha gave maximum yield, but it was not significantly superior to potash @ 150 kg K_2O/ha. He concluded that N & K_2O @ 100 and 150 kg/ha respectively was optimum for cassava at Vellayani conditions.

Kingchol (1971) in Thailand found that for good yield of cassava 40 ppm K was sufficient and that K fertilication was required only below this level.

Kumar et al. (1971) from the results of field experiments conducted at CTCRI, Trivandrum, found that the tuber yield of cassava increased progressively with application of K_2O upto 100 kg/ha (basal application of 100 kg N and 100 kg P_2O_5/ha apart from K). Optimum level of K was found to be 103 kg K_2O/ha.

According to Harper (1973) the ratio of N:K is critical as far as manuring of cassava is concerned.

Rodriguez (1975) found that in Bello and San Jos del Nus, best results were obtained with 100 kg/ha of N and 120 kg K_2O/ha.

Rajendran et al. (1976) from field experiments conducted in acid laterite soil at CTCRI, Trivandrum, reported that 100 kg N and 100 kg K_2O/ha was the optimum for cassava and that the optimum N:K ratio is 1:1.

Natarajan (1979) found that eventhough potash @ 150 kg K_2O/ha gave significantly higher yields than lower levels, the N:K combination of 150:90 kg/ha gave highest yield (39.03 t/ha) in variety H-165. Maximum starch per cent was obtained with N & K application @ 150 kg/ha each.

Pushpadas and Aiyer (1976) from a split plot experiment at Vellayani found that maximum yield (29.1 t/ha) was obtained for variety M4 when potash was applied @ 250 kg/ha and for variety H-105 maximum yield of 25.9 t/ha was obtained at a potash rate of 125 kg K_2O/ha. Hence the $N:K_2O$ ratio was 100:129 for the hybrid variety H-105 and 100:250 for variety M4.

Ngongi et al. (1977) reported that K_2O @ 120 kg/ha was adequate for cassava in Colombia.

Asokan and Sreedharan (1977) from field experiments in Vellayani with variety H-97 reported that maximum tuber yield was obtained at 112.5 kg K_2O/ha. The optimum N:K ratio according those authors was 100:112.5.

Spear et al. (1978) found that in constant solution cultures cassava required 2-6 μM of K to produce maximum yield.

Sittiboot et al. (1978) reported that in Thailand the production of cassava was higher when potassium was applied @ 200 kg K_2O/ha. The available K of the soil was 10-20 ppm. N and P_2O_5 were applied @ 100 kg/ha each.

Asokan and Sreedharan (1978 & 1980) obtained maximum yield of 34.3 t/ha for variety H-97 @ 135 kg K_2O/ha. Nitrogen was applied @ 100 kg N/ha. They found that the optimum $N:K_2O$ ratio was 100:135.

According to Gomes and Howeler (1980) for production of cassava in low fertility soils of Brazil potash application was more effective than nitrogen in inducing yield increments per kg of added nutrient.

Muthuswamy and Chiranjivi Rao (1980) studied the fertiliser response functions in two varieties viz., Burma and H-165 at Coimbatore. They observed that the economic doses of N and K were 89.33 and 262.4 kg/ha respectively for a predicted yield of 43.42 t/ha. The economic N:K ratio was worked out to be 1:2.9.

Asokan *et al.* (1980) in red sandy loam soils of north Malabar reported that in variety H-1687 the maximum yield (30.25 t/ha) was obtained when nitrogen and potash were applied @ 120 kg/ha respectively. They also found that the yield reduced significantly at 180 kg K_2O/ha.

Ramaswamy and Muthukrishnan (1980) from investigations on nutritional requirements of varieties H-1687 and H-2304 at Coimbatore showed that the N:K ratio was 1:1 and the optimum dose of potash was 60 kg/ha.

Ramanathan *et al.* (1980) from field experiments in Coimbatore and Bhavanisagar reported that N and K interaction was significant at Bhavanisagar and that the optimum doses of N and K were respectively 80 kg N and 120 kg K_2O/ha for higher yield.

Sheela (1985) reported that the optimum $N:K_2O$ ratio for cassava at Vellayani conditions was 100:150.

Moraes *et al.* (1981) in Brazil found that when soil K was low the response of cassava was only upto 80 kg K_2O/ha. When soil K was high there was no response.

Nair (1982) from a 3^3 confounded factorial experiment found that the N:K_2O ratio for red loam soils at Vellayani conditions was 100:125 and that for sandy loam soils (Mayangalam) was 100:200.

Asokan and Vikraman (1983) from experiments at Vellanikkara (sandy loam soil) with var. H.2304 and M4 concluded that the optimum N:K_2O ratio was 100:50 in soils having moderate N and K.

3. Time of application of N, P & K

Many research workers (Normanha 1951; Silva 1965; Samuels 1970; Mandal *et al.* 1971) have recommended that 1/2 dose of N and K fertilizers should be applied as basal, with a top dressing of the remaining half at 2-3 months for cassava.

Kumar *et al.* (1971) reported best results in Trivandrum, Kerala, with the application of half dose of N at planting time and half at 1 month. At the same place Asokan and Sreedharan (1977) recommended a split application of K, 1/3 as basal, 1/3 at 2 months and 1/3 at 3 months.

CTCRI (1970) reported highest yields with split application of N (1/2 basal and 1/2 at 2 months) P (1/2 basal and 1/2 at 2 months) and K (1/2 basal and 1/2 at 2 months). In other trials CTCRI (1971) a basal application of P was found to be significantly superior to split application of this element.

Kumar *et al.* (1971) recommended half dose of K as basal and the other half after one month.

Rodrigues (1975) obtained highest yields when NPK fertilisers were applied at planting rather than as split application.

Lozano *et al.* (1976) recommended band application of N, half at the time of planting and the other half 2-3 months after planting.

CIAT (1976, 1978) found no significant differences between a basal and split application of either N or K fertilisers, but a basal application of P was superior to a split application (CIAT, 1976).

Asokan and Sreedharan (1978) from field experiments at Vellayani with variety H-97 found that three split application of K (1/3 basal + 1/3 two months after planting + 1/3 three months after planting) had given better results.

In CIAT (1979) a split application of N with one third applied at 0, 30 and 90 days was found to be superior to basal application.

Nair (1982) from 3^3 factorial experiment (confounded) found that at Vellayani and Kayangulam N and K gave maximum yields when applied as three splits (1/3 as basal + 1/3 at 2 months + 1/3 at 3 months).

Asokan and Vikraman (1985) from experiments conducted at Vellanikkara, with varieties H-2304 and M4, observed that application of N and K_2O as 3 splits (1/3 at 15th day + 1/3 at 60 days + 1/3 after 90 days) was found to be beneficial for maximum yield.

4. <u>Response of cassava to N, P and K</u>

Fertiliser experiments with cassava have been conducted throughout the tropical countries of the world. But the results are often only of local value unless the soil and climate are well characterised so that extrapolation to other areas with similar conditions is possible. The response to individual elements have been reviewed here.

Boop (1937) found that cassava responded well to application of potassium @ 125-250 kg K/ha in Inceptisols of Java, Indonesia.

Grossman and Assis (1951) got response of cassava on sandy soils for 100 kg K_2O/ha.

Normanha (1951, 1960 and 1961) reported good response of cassava to application of 58-116 kg P_2O_5/ha and 50-100 kg K_2O/ha in Sao Paulo, Brazil.

In Madagascar, Anonymous (1952) and De Geus (1967) got response of cassava to 30-60 kg N/ha, 127 kg P_2O_5/ha and 110 kg K_2O/ha.

According to Acosta and Perez (1954), cassava responded only to nitrogen @ 50 kg N/ha in Costa Rica. But Schmitt (1959) reported response of cassava to N, P and K @ 60-70 kg N/ha, 58-67 kg P_2O_5/ha and 130 kg K_2O/ha in the same place.

Irving (1956) in a light acid soil of eastern Nigeria got response of cassava to 9-27 kg N/ha and 20 kg K_2O/ha.

Roche et al. (1957) found that cassava responded to 100 kg N/ha and 160 kg K_2O/ha in Madagascar.

Ghosh (1960) from experiments on cultivators' field in an oxisol in Kerala reported response of cassava to 73.6 kg P_2O_5/ha and 160 kg K_2O/ha.

Pillai (1960) studying the response of N, P & K found that maximum yield of tuber for var. H-97 at Vellayani conditions was for 100 kg N, 50 kg P_2O_5 and 150 kg K_2O/ha.

Stephens (1960) from fertiliser trials in cultivator's fields in Ghana concluded that only 25 kg N/ha and 22 kg P_2O_5/ha are necessary for cassava.

Cours et al. (1961) got response of cassava to N, P and K @ 30 kg N/ha, 260 kg P_2O_5/ha and 120 kg K_2O/ha in Madagascar.

Nongopagan (1962) reported that in Thailand cassava responded only to phosphorus at 31-47 kg P_2O_5/ha.

In a lateritic soil at Costa Rica, Murillo (1962) got no response in cassava to application of N, P or K in a lateritic soil.

Cheng (1969) found that an increase of 1299 kg of roots was obtained by application of 90 kg/ha K_2O for cassava in Taiwan.

Albuquerque (1966) in Amazon estuary of Brazil reported that cassava responded to P_2O_5 and K_2O only @ 90 and 100 kg/ha respectively.

Silva and Freire (1968) in sandy soils of Sao Paulo, Brazil, got response of cassava to 60-120 kg K_2O/ha.

Vijayan and Aiyer (1969) in an oxisol soil of Kerala, India, reported that cassava responded up to 100 kg N, and 100-150 kg P_2O_5/ha, keeping the level of K constant at 100 kg K_2O/ha.

Chew (1970, 1971) found that application of 160 kg N/ha, 49 kg P_2O_5/ha and 110-146 kg K_2O/ha was the requirement of cassava in a peat soil in Malaysia.

Samuels (1970) got response of cassava to potash only @ 100 kg K_2O/ha in Puerto Rico.

From annual reports of CTCRI (1970, 1971, 1972 and 1973) Trivandrum, India, it is seen that cassava responded to 50-100 kg N, 100-150 kg P_2O_5 and 100 kg K_2O/ha in oxisol soils.

Kumar et al. (1971) in an oxisol in Kerala, India got response of cassava to 100 kg K_2O/ha. Mandal et al. (1971) in the same soil reported response of cassava to 100 kg N/ha.

Takyi (1972) in a forest soil at Ghana got response of cassava to application of 60 kg N/ha and 45 kg P_2O_5/ha. Mean response for K was 1.4 per cent for K_2O @ 253 kg/ha.

In Thailand, Gilitboot et al. (1973) reported that for highest yield (33.69 t/ha) N, P_2O_5 and K_2O were required @ 100:100:50 kg/ha respectively.

Shanmugam and Sreenivasan (1973) found that at Tamil Nadu Agricultural University, Coimbatore, N, P_2O_5 and K_2O @ 50:90:150 kg/ha increased cassava yields by 116 per cent.

Ahmad (1973) reported that cassava responded to 124 kg N, 69 kg P_2O_5 and 110 kg K_2O/ha in Serdang, Malaysia.

In Kuala Lumpur, Malaysia, Cheing (1973) got response to 150 kg N, 67 kg P_2O_5 and 160 kg K_2O/ha for cassava.

Amon and Adetunji (1973) reported significant response of cassava to application of 25 kg N and 60 kg K_2O/ha in western Nigeria.

Tarazona et al. (1973) in an inceptisol at Colombia found the best combination of NPK for cassava to be 50-60 kg N, 293 kg P_2O_5 and 50-60 kg K_2O/ha.

Kanapathy (1974) found that in a Malaysian peaty soil, cassava responded well to 120 kg N/ha and 90 kg K_2O/ha.

Nunes et al. (1974) got response of cassava to only 69 kg P_2O_5/ha in Rio de Janeiro, Brazil.

Sittibusaya et al. (1974) found that in Thailand for highest yields N, P_2O_5 and K_2O were required @ 100:100:125 kg/ha respectively.

Fox et al. (1975) in an ultisol at Puerto Rico got response of cassava for 120 kg N/ha.

In inceptisols of Antioquia, Colombia, Rodriguez (1975) got best yield of cassava by applying 145 kg N, 190 kg P_2O_5 and 46 kg K_2O/ha.

CIAT (1975) reported response of cassava to 100 kg N/ha in oxisols of Llanos, Colombia.

Hadi and Gozallie (1975) in Java, Indonesia got response of cassava to 90 kg N, 36 kg P_2O_5 and 0-50 kg K_2O/ha.

Pushpadas and Aiyer (1976) found that under Vellayani conditions the optimum N & P dose was 100 kg N and P_2O_5/ha respectively for cassava varieties., H-105 and M4. But for the hybrid H-105 the optimum potash rate was 125 kg K_2O/ha while that for variety M4 was 250 kg K_2O/ha.

Ngongi (1976) from field experiments conducted in a Mollisol at Cauca Valley, Colombia got best results with 120 kg K_2O/ha. Again Ngongi (1976) in an oxisol at Llanos, Colombia got response to 100 kg N and 240 kg K_2O/ha.

In the oxisols of Llanos, Colombia, CIAT (1976) reported response of cassava to 294-390 kg P_2O_5 and 100 kg K_2O/ha.

Curva (1977) in an ultisol of Tarapoto, Peru reported response of cassava to 116 kg P_2O_5/ha.

Sittibusaya and Kumarohita (1978) in podzolic soils of Northeast Thailand got response of cassava to 50-100 kg N and 50-100 kg P_2O_5/ha while in Southeast Thailand response to phosphorus was @ 100-200 kg P_2O_5/ha.

Varma and Grewal (1979) reported response of cassava in acidic brown hill soils of India for 100 kg N, 44 kg P_2O_5 and 120 kg K_2O/ha.

Table 4. The response of cassava to application of N, P and K (kg/ha) in different parts of the world

Country	Region	Soil	N	$P(P_2O_5)$	$K(K_2O)$	Reference
Puerto Rico		Ultisol	120	..	..	Fox *et al.*, 1975
					83(100)	Samuels, 1970
Costa Rica			60-70	(60-70)		
				26-30	103(124)	Schmitt, 1955
			50		..	Acosta and Perez, 1954
Colombia	Various	Incept-oxisol	50-60	131(300)	(50-60)	Tarazona *et al.*, 1973
					42-50	
	Antioquia	Inceptisols	145	85(190)	38(46)	Rodriguez, 1975
	Cauca Valley	Mollisols	..	..	100(120)	Ngongi, 1976
	Llanos	Oxisols	100	..	200(240)	Ngongi, 1976
	Llanos	Oxisols	100	..	..	CIAT, 1975
	Llanos	Oxisols	..	87-175	133(160)	CIAT, 1976
				(200-400)		
Peru	Tarapoto	Ultisol	..	52(120)	..	Curva, 1977
Brazil	Sao Paulo			26-52	(30-100)	
				(60-120)	25-83	Normanha, 1951, 1960 & 1961
	Sao Paulo	Sandy	..		50-100	Silva and Freire, 1968
					(60-120)	
	Rio de Janeiro			29(65)	..	Nunes *et al.*, 1974
	Minas Gerais	Oxisols			50(60)	Correa *et al.*, 1979
	Bahia	Oxisols	200	30(70)	..	Santana *et al.*, 1979
	Bahia	Oxisols	..	26-52	(60-120)	
					50-100	Gomes *et al.*, 1979 a
	Amazon estuary	..		44(100)	150(180)	Albuquerque, 1968
	..	..	60	22(50)	33.2(40)	Malvolta, 1961

contd....

Nigeria	Western		25	-	50(60)	Anon & Adetunji, 1975
	Western	Various	60-90	..	-	Obigbesan & Fayemi, 1976
	Western	Light acid	9-27	..	17(20)	Irving, 1956
Ghana	Forest	Forest	25	10(22)	..	Stephens, 1960
			60	20(44)	..	Takyi, 1972
Madagascar			50-60	57(130)	92(110)	Anon., 1952, De Guss, 1967
			100	-	150(180)	Roche *et al.*, 1957
				120(270)	100(120)	Coure *et al.*, 1961
Thailand		..	..	14-21 (31-47)	..	Hongsapagan, 1962
India	Kerala	Laterite	100	..	..	Mandal *et al.*, 1971
		..	..	..	83(100)	Kumar *et al.*, 1971
		..	100	..	83(100)	Rajendran *et al.*, 1976
		..	50-100	44-65 (100-150)	83(100	CPCRI, 1970, 1971, 1972, 1973 1974, 1975, 1976, 1977, 1978, 1979, 1980 & 1981
		..	60	..	50(6)	KAU, Annual Report 81-82
		Red loam	150	..	41.5(50)	Natarajan, 1975
		..	100	44-65 (100-150)	83(100)	Vijayan and Aiyer, 1969
		..	..	..	93(112.5)	Asokan & Sreedharan, 1977
		..	100	(22(50)	125(150)	Pillai & George, 1978
		..	..	..	93(112.5)	Asokan & Sreedharan, 1978, 1980
		..	..	..	93(112.5)	Sheela, 1981
		..	120	..	99.6(120)	Asokan *et al.*, 1980

contd..

India	Kerala	Red Loam	150	44(100)	207.5(250)	Pushpadas & Aiyer, 1976
		..	125	..	103(125)	Nai[illegible], 1982 (Unpublished)
		..	..	..	83(100)	KAU Annual Report, 1982
		Sandy clay loam	..	..	41.5(50)	Asokan & Vikraman, 1983 (Unpublished)
		.. Sandy loam	125	..	165(200)	Nai[illegible], 1982 (Unpublished)
India	Tamil Nadu (Coimbatore	Black cotton soils	89	..	215.8(260)	Muthuswamy, 1978
		Red soils	60	26.4(60)	49.8(60)	Ramaswamy & Muthukrishnan, 1980
		..	80	..	99.6(120)	Ramanathan *et al.*, 1980
		Black cotton soils	83	..	195.8(236)	Muthuswamy and Chiranjivi Rao, 1980
	Karnataka	--	75	33(75)	63.9(76)	Vidyachandra & Rao, 1980
	Orissa	--	100-150	..	..	Saraswat & Chettiar, 1976

Correa et al. (1979) in oxisols of Minas Gerias, Brazil got response of cassava to 60 kg K_2O/ha. Santana et al. (1979) in the same soil at Bahia, Brazil, found that cassava responded to 200 kg N and 67 kg P_2O_5/ha.

Gomes et al. (1979) found that in oxisols of Bahia, Brazil, cassava responded well to 58-116 kg P_2O_5 and 60-120 kg K_2O/ha.

Santana et al. (1979) reported that cassava responded to 200 kg N and 67 kg P_2O_5/ha in Brazil. Kerala Agricultural University in its Package of Practices(1981) recommended the following fertiliser rates which was found optimum for cassava in Kerala.

Variety	Nutrient dose (kg/ha)		
	N	P_2O_5	K_2O
H-97 and H-226	75	75	75
H-165, H-1687 and H-2304	100	100	100
M4 and local	50	50	50

Asokan and Sreedharan (1978 and 1980) obtained maximum yield (34.5 t/ha) of tubers at N: P_2O_5: K_2O rate of 100:100:135 kg/ha respectively.

Malavolta (1981) quoted rates of N, P_2O_5 and K_2O recommended for cassava in Brazil as 60, 50 and 40 kg/ha respectively.

5. NPK requirements of some other tuber crops

According to Irving (1956) and Obihara (1962) on leached acid sandy soils of Eastern Nigeria the response in yams could be observed only with nitrogen and potash.

Taylor et al. (1959) in light textured soils of California found that K was necessary @ 135-150 kg/ha for maximum yields in potato. Above 150 kg K_2O/ha, potash was excessive.

From experiments conducted on yams in eastern Nigeria Anonymous (1962) found that the optimal rate of potash was 26.9 kg K_2O/ha when N and P were applied @ 35.9 kg/ha. But when N and P were increased to 53.8 kg/ha the optimum rate rose to 80.7 kg/ha.

Boyd and Dermott (1964) reported that for heavy soils P requirement for potato was 125-188 kg/ha. In sand and sandy loams optimum K_2O was 250 kg/ha.

Amon (1965) on sedimentary soils under rain forest vegetation in Western Nigeria also reported responses of N and K to yams.

Pena and Plucknet (1967) got maximum response in Colocasia esculenta in Hawaii for 1344 kg K_2O/ha.

Greig (1967) found that for sweet potato in Sandy loam soils of Kansas the optimum dose of N, P_2O_5 and K_2O was 28, 125 and 67 kg/ha.

According to A.C.E.R.C. Report (1969) potash @ 180 kg/ha boosted the yield of sweet potato from 12 to 27 per cent. Above this level K application had an adverse effect.

For Western Nigeria Amon and Adetinji (1970) suggested

28-56 kg N/ha and 67 kg K_2O/ha, compared with 160 kg K_2O/ha in Trinidad according to Ferguson and Hynes (1970).

Ferguson and Harynes (1970) found that chinese yams (D. esculenta) responded highly to K application upto 160 kg K_2O/ha.

Gadghal (1973) found that 50 kg K_2O/ha was most beneficial for sweet potato under Delhi conditions.

Uriyo and Kesseba (1973) in oxisols of Tanzania reported that the yield of sweet potato was highest (42.7 t/ha) with 200 kg K_2O/ha alone.

In the University of Ibadan, Nigeria, Obigbesan (1973) reported that yam varieties differed in their responses to potash fertilization. Application of 44.6 kg K_2O/ha increased yield of yellow yam (Dioscorea cayenensis) by 33 per cent as compared to 21 per cent yield increase in white variety (D. esculenta). It required 56 kg K_2O/ha to give a comparative yield increase of 38 per cent in the latter variety. White D. rotundata continued to respond to additional supply of K upto 78.4 kg K_2O/ha. D. cayenensis failed to respond beyond 33.6 kg K_2O/ha.

Nair et al. (1976) reported that under Vellayani (Kerala) conditions the optimum level of N for sweet potato was 50 kg/ha, beyond which it resulted mainly in N removal by aerial vegetative portions.

Nambiar et al. (1976) found that for sweet potato under Kerala conditions the most beneficial dose of N was

100 kg/ha which gave 20.5 t/ha compared to 8.1 t/ha for N_{50} and 9.4 t/ha for N_{75}.

According to Shukla *et al.* (1975), 150 kg N, 60 kg P_2O_5 and 150 kg K_2O/ha was the optimum dose for sweet potato at Benaras.

Steeghs (1979) was of the opinion that under Trivandrum conditions K is the most critical nutrient so far as yield of sweet potato is concerned. According to him 75 K_2O/ha is optimum for sweet potato.

KAU (1981) recommended nutrient doses for the following tuber crops as shown below.

Tuber crop	Nutrient dose (kg/ha)		
	N	P_2O_5	K_2O
1. Sweet potato	75	50	75
2. Colocasia	80	50	100
3. Amorphophallus	80	60	100
4. Dioscorea (*alata* and *esculenta*)	80	60	80

6. Potassium nutrition in relation to incidence of pests and diseases

The nutrient deficiency in tuber crops leads to not only lower yields but also pre-disposes it to the incidence of several pests and diseases. Potassium deficient plants invariably suffer more severely from diseases and attack due to pests than well nourished ones. On a world wide basis it has been reported from observations on several crops that adequate potassium nutrition reduces incidence of both plant diseases and attack by pests more than any other nutrient.

Chaboussou (1972) reported that potassium fertilization controls some insects like mites. Foliar sprays of potassium nitrate was effective in controlling the number of mites.

Adenji and Obigbasen (1976) studied the reaction of susceptible and a tolerant cultivar of cassava to infection by bacterial blight disease under four levels (0, 60, 90 and 120 kg/ha) of potassium nutrition. At 0 and 60 kg/ha, the wilt was 74.4 and 70.8 and 56.2 and 44.4 per cent in susceptible and tolerant cultivars respectively. Significant reduction in wilt was obtained at 108 kg K_2O/ha in both varieties.

Kanwar (1976) observed that K deficiency reduced the resistance of plants to infection by bacterial and fungal pathogens which frequently infect chlorotic areas between the veins.

7. Plant analysis and nutrient studies of different parts of cassava

Cours *et al.* (1961) studied the effect of various fertilisers on the nutrient levels in the phelloderm of the main stem in cassava. Application of N had a positive effect on the N content of the phelloderm. P had no effect, while K had a highly significant positive correlation.

Pushpadas and Aiyer (1975) showed that the middle group of petioles (the total leaves of the stem being divided into three portions viz., the upper, middle and lower) served as the 'reflect' for analysis of N, P, K & Ca. They found that 4½ months stage was the most suitable time for reflect analysis.

Rajendran *et al.* (1976) studying the effect of potassium fertilisation of cassava in laterite soil found that potassium concentration in plant parts was as follows:

Levels of K_2O (kg/ha)	Tuber (K %)	Leaf and stem (K%)
0	(0.45)	(1.07)
50	(0.85)	(1.45)
100	(1.08)	(1.83)
150	(1.23)	(1.88)

According to Pushpadas *et al.* (1976) at Vellayani, the mean K_2O content in petioles of cassava were more in variety H-105 than M4 at all three stages i.e. 62, 136 and 203 days.

	K (%) in petioles					
	62 days		136 days		203 days	
	M4	H-105	M4	H-105	M4	H-105
Varietal mean	1.85	2.04	2.21	2.70	1.63	2.26

Howeler (1978) has reported approximate nutrient concentrations in different plant parts of cassava. Approximate concentration of each nutrient in a crop producing 30 t/ha tubers is given below:

Nutrients	Concentration per cent			
	Roots	Stems	Leaves	Petioles
Nitrogen	0.36	0.66	4.18	1.43
Phosphorus	0.10	0.34	0.26	0.14
Potassium	0.73	1.69	1.20	2.35

Asher et al. (1980) is of the opinion that the critical concentration of nutrients in cassava vary with age and some other factors. They recommended the youngest fully expanded leaf (YFEL) blades as the best indicator of nutritional status. Again they were of the opinion that 2-5 months period was the best time for studying critical concentration of nutrients in cassava.

Nair and Mohan Kumar (1980) studying the effect of different sources of potassium on cassava, variety H-97, at Sreekariyam reported the following K contents in plant parts:

K content in plant parts (%)		
Tuber	Leaf	Stem
0.74-1.12	1.20-1.34	0.72-1.18

8. <u>Physiological and biochemical effects of potassium on yield and other attributes</u>

The effect of potassium in increasing the starch content of tubers and decreasing the nitrogenous material responsible for bitterness in cassava was recognised by Blin (1905).

Eaves and Leafe (1953) found that K application had a favourable effect on the production of dry matter, starch and protein in potato.

Dolhius (1954) reported that K-deficiency increased the linamarin content of cassava tubers.

According to Malvolta *et al.* (1955) in the absence of K (in sand culture experiments), the weight of roots decreased, while that of shoots increased.

Black and Cairns (1958) reported that the production of dry matter, starch and protein content of potato was positively correlated with potash application.

Chadha (1958) from fertiliser experiments on cassava in Kerala State found that the response of potash varied from 19 to 43 per cent for 90 kg K_2O/ha and from 25 to 75 per cent for 180 kg K_2O/ha.

Black and Cairns (1958) reported a positive relationship with drymatter, starch and protein in potato.

Ward (1959) got positive response of K on starch, drymatter and protein in potatoes.

De.?. (1959) also found that the carbohydrate content in potato had a positive response to K application.

Ward (1959) reported that K deficiency in potato resulted in low starch content of tubers. He found a positive relationship of K on drymatter content, starch and protein in potato.

Cours *et al.*(1961) found that application of potassic fertilisers increased the NPK content in plant, yield and density of tubers in cassava.

According to Lachover and Arnon (1962) in sandy clay loam soil, application of K increased starch content of cassava and the quality and starch content correlated with the exchangeable K in the soil.

Richard (1964) reported that higher levels of potash (330 kg K_2O/ha) depressed yields perhaps due to chloride injury.

Tsuno and Fujise (1965) found that K participate in protein metabolism of sweet potato. They were of the opinion that promotion of growth by K may be associated with promotion of photosynthetic activity through accelerated translocation of photosynthates.

According to Humphries (1967) carbohydrate accumulation slows down photosynthesis.

Pillai (1967) obtained significant positive response of K on cultivar H4 and found that K increased the edible portion, drymatter and starch content in tapioca tubers.

Fujise and Tsuno (1967) found that drymatter production in sweet potato was positively and significantly correlated with K_2O/N ratio.

Obigbesan (1973) reported that K application increased drymatter and starch and decreased HCN content of cassava roots.

Mengel (1979) showed that K favourably affected sugar synthesis and its translocation in plants.

Pushpadas and Aiyer (1976) reported that K increased the edible portion, drymatter content and starch content of tubers, but decreased the crude protein and HCN content of tubers.

Sukla *et al.* (1976) found that the drymatter, starch and protein contents of potato tubers increased as levels of K application increased. Sukla and Singh (1976) also reported the same relationship of K with starch, drymatter and protein content of potato.

Asokan and Sreedharan (1977) reported that the starch content of cassava increased from 26.2 to 30.5 per cent in plots receiving potash @ 45 kg and 135 kg K_2O/ha respectively. The HCN content was reduced from 147 µg/g to 112 µg/g, the drymatter increased from 37.9 to 39.1 per cent and crude protein decreased from 2.72 to 2.22 per cent in potash treatments @ 45 and 135 kg K_2O/ha respectively.

Ngongi *et al.* (1977) found that a high correlation existed between cassava yield and plant fresh weight per hectare.

Pillai and George (1978) found that K application increased the weight of edible portion, drymatter and starch content in cassava tubers. Beyond 150 kg K_2O/ha, K reduced the protein content.

According to Gomes *et al.* (1980) K application increased the starch content of tubers consistently.

Muthuswamy and Chiranjivi Rao (1981) reported that K application reduced the HCN content in tubers of cassava. With maturity fibre content also decreased.

According to Edwards (1982) K fertilization increased tolerance to stress in plants.

9. Critical concentration of N, P and K

The correct rate of application of various nutrients depends entirely on the soil fertility and texture. Fertilizer recommendations are generally based on soil analysis and fertilizer experiments, while corrective application can be made based on foliar analysis. For interpretation of analytical results, many investigators have determined the relationship between plant growth (or yield) and the "available" nutrient content of the soil or the total nutrient content of a certain index tissue of the plant, generally the youngest fully expanded leaves (YFEL). The plant's nutritional requirement is reported in terms of "critical concentrations" i.e. the concentration in soil or plant tissue, below which the plant will respond to application of that nutrient and above which no response is to be expected.

Critical concentrations in soils for cassava have been reported for a few elements by several investigators, but their usefulness is limited due to diversity in methods of soil analysis.

Roche et al. (1957) found that 0.06 me/100 g was the critical level of potassium for cassava from soil analysis. Obigbesan (1977) reported that the critical level of potassium for cassava was 0.09 to 0.15 me/100 g (NH_4 - acetate method).

Howeler (1978) found that the critical level of potassium for cassava was 60 µg/g (North Carolina extract i.e. 1 N HCl + 0.025 N H_2SO_4). Howeler (1978) reported a critical level of 7 µg/g of phosphorus for cassava (Bray-I extract). The same investigator using Bray-II extractant found that 10 µg/g was the critical limit of P. Using Olsen-EDTA extractant, he again got a critical value of 8 µg/g for phosphorus.

The critical nutrient concentrations in cassava tissue reported in literature are summarised below:

Prevot and Ollagnier (1950) showed that the critical level of K in cassava leaf as determined by foliar analysis was 1.2 per cent.

Fox et al. (1975) found that 5.1 per cent N was the critical concentration in YFEL leaf blades of cassava.

CIAT (1976) reported a critical concentration of 4.65 per cent N in YFEL leaf blades.

According to Lozano et al. (1976) normal levels of K in upper leaf blades of cassava were 1.2 to 1.8 per cent.

Fernando (1977) found that the critical concentration of nitrogen in cassava shoots is 4.2 per cent.

CIAT (1977) found that critical concentration of P was 0.44 per cent in YFEL leaf blades.

Howeler (1970) by analysing YFEL blades of cassava arrived at a critical concentration of 5.7 per cent for nitrogen.

For potassium Spear et al. (1978 a, b) reported critical concentration of 1.1, 0.8 and 0.6 per cent in YFEL leaf blades, YFEL petioles and stems of cassava respectively. They also found that the critical concentrations varied in different containers in pot culture experiments. The critical concentration of K was 1.1 per cent in 8 litre container, 0.3 per cent in 2.5 litre and 0.5 per cent in 1 litre container.

Jintakanon et al. (1979) reported that the critical value of P for the shoots is 0.47-0.66 per cent.

In general it can be concluded that a fertilizer response is not likely when the YFEL blades contain more than 5.0 per cent N, 0.4 per cent P and 1.2 per cent K.

Rate of NPK application based on plant response and fertiliser trials

According to Chew (1971) in acid peat soils of Malaysia, 210 kg N, 111.5 kg P_2O_5 and 132 kg K_2O/ha was the optimum dose for cassava.

Amon and Adetunji (1973) reported that the recommended dose of nutrients in Nigeria for cassava is 28 kg N + 67 kg K_2O/ha.

Badillo Feliciano and Lugolopez (1976) reported that 78 kg N + 67 kg P_2O_5/ha gave maximum yield of cassava tubers at Peutro Rico.

Shanmugam and Sreenivasan (1973) found that at Tamil Nadu Agricultural University 50:50:150 kg NPK/ha (50:112:180 kg N, P_2O_5 & K_2O/ha) increased yields of cassava by 116 per cent.

Nume *et al.* (1974) found that in Brazil P was the major factor limiting cassava yields. 40 kg/ha P_2O_5 was recommended which increased yields upto 86 per cent.

Rodriguez (1975) from several field experiments conducted in Palestine (State of Caldes) found that maximum yield of cassava was reached by applying 149 kg N, 194 kg P_2O_5 and 46 kg K_2O/ha. Yields were greater when applied at the time of planting. In Bello and San Jos del Nus, best results were obtained with 100 kg N, 200 kg P_2O_5 and 100 kg K_2O/ha.

Kumar (1978) reported that in acid laterite soil the recommended dose is 100:100:100 kg N, P_2O_5 and K_2O/ha.

KAU (1978 and 1981) in its package of practices also recommended 100 kg N, 100 kg P_2O_5 and 100 kg K_2O for cassava in Kerala State for high yielding varieties like H-165, H-1687 and H-2304.

10. Potassium deficiency symptoms in cassava

Accurate diagnosis is essential if nutritional problems are to be dealt with effectively. Visual symptoms of nutrient deficiencies of the crop play an important role in the diagnosis under field conditions. Visual symptoms of potash deficiency in cassava are discussed below as observed by different research workers.

Nijholt (1935) reported that continuous cassava production without adequate potassium fertilisation may lead to potassium deficiency.

Cours et al. (1961) found that potassium deficiency reduced the development of anthracnose (Colletotrichum or Glomerella manihotis). However no known cassava pathogens could be isolated from the petiole lesions in the study of Spear et al. (1978 b).

According to Cours et al. (1961) and Spear et al. (1978 b), as in the case of nitrogen and phosphorus, potassium content decreased markedly from upper to lower leaves in potassium deficient plants.

According to Krochmal and Samuels (1968) K deficiency was characterised by purpling or bronzing of leaf followed by marginal necrosis.

Howell (1974) reported yellowing or browning of leaf tips and adjacent margins of older leaves of potassium deficient plants.

Lozano et al. (1976) reported that K deficiency in cassava reduces height and produce narrow and fewer lobes.

Ngongi et al. (1977) reported that potassium deficiency is generally corrected by band application of potassium chloride or potassium sulphate, the latter being preferred in soils of low sulphur status.

Spear *et al.* (1978 b) found that excessive K fertilization may lead to magnesium and/or calcium deficiency due to depression of the uptake of these elements. They have observed the development of longitudinal grooves in the upper stem internodes of K deficient plants and purple discoloration on petioles.

According to Ashar *et al.* (1980) deficiency of K is mainly characterized by a severe reduction in plant height, thin stems, short petioles and small leaves. In early stages K deficiency symptoms include the appearance of small purple spots on older leaves, upward curling of leaf margins, and in some cases downward curling of leaf tips. As the deficiency intensifies, chlorotic areas develop at the tips and along the margins of the leaves and eventually join up to form border necrosis.

<u>Comparison of K-deficiency in different plants</u>

Wolfgang Bussler (1964) in his book on "Comparative examinations of plants suffering from potash deficiency" described certain symptoms making use of the results of several experiments of his own and of the collective works of Wimmer (1909), Turrentine (1937), Boredel Kitchen (1948), Bennmeister (1955) and Penningsfeld (1960). Two characteristics which recur in all the descriptions by the above workers are:

(1) The first sign of K deficiency never occurs on the younger leaves

(2) The place favoured for general injuries are leaf tips and margins of leaves

Tayler *et al.* (1959) on light textured soils in California found that K deficiency in potato was accompanied by leaf mottling, scorch and rolling.

According to Dussler (1964) K-deficiency in cosmos bipinnatus showed decrease in growth, and brown necrosis on leaf margins. The injuries appeared on older leaves. Leaf curling was also a symptom of K-deficiency. At higher temperature and often at mid-day the K-deficient leaves drooped although there was no shortage of water.

Spencer and Ahmed (1967) noticed that in sweet potato plants deficient in K, the colour of leaves growing near the vegetative point became pale and the surface became irregular. Growth was restricted, petioles were shortened. Later interveinal chlorosis started in older leaves beginning at the tips of laminae and extending around the margin. Dark brown necrosis on leaf margins appeared and finally leaves died. Yield was reduced considerably.

Kanwar (1976) studying K-deficiency symptoms found that in potato, the lamina became crumbled and raised. Interveinal chlorosis and leaf tip scorching along margins. The roots were poorly developed and yield decreased. According to the author legumes, cereals and tuber crops are very susceptible to K-deficiency. In barley, numerous small brown areas develop in areas between vein. In root crops eg. sugar beet, the roots are tender and poorly developed. In K-deficient fruit trees like mango, papaya, guava and custard apple the common symptom is chlorotic mottling between veins and marginal scorching of older leaves. Premature leaf shedding and 'die-back' are other symptoms.

11. Quality parameters of cassava

A review of literature indicates that the word "quality" with reference to cassava, is often used by many workers when they determine and discuss the results of the starch content and HCN content of tubers in relation to variety, manurial experiments etc. However there are very few publications where in various starch quality parameters have been discussed either in relation to varieties or in relation to nutritional parameters.

ISI (1960) gave some specifications for tapioca starch for use in the textile industry. In this they have specified properties such as starch content, crude fibre, viscosity and HCN content.

Rosenthal (1971) examined the characteristics of eleven varieties of cassava starches in the State of Minas Gerais, Brasil, and reported that the granule size varied from 3-10 µ in smaller granules and 18-26 µ in bigger granules. The gelatinisation temperature varied from 61-63°C and the amylose content varied from 15.3-17.5 per cent.

Prema *et al.* (1975) considered the following qualities of cooked tubers for acceptability and quality by village women who used cassava as a staple in their diet:— sweet, watery, starchy, bitter and watery bitter.

Raja *et al.* (1978) studied the effect of fractional sieving on quality aspects of cassava flour and found that grinding and sieving showed that particles bigger than 85 mesh have lower starch but better cooking quality compared to finer fractions. Free sugars, protein and fibre contents were higher in coarser particles. Amylose content had no correlation with particle size of starch.

Moorthy and Maini (1980) studying the differences on the properties of cassava starch from different cultivars found that there are differences in properties like granule size, alkali number, amylose content, pasting temperature, viscosity and swelling volume. They have observed that varieties having better and more acceptable cooking qualities contained higher amounts of amylose. According to them amylose content and gelatinisation temperature of starch may be the major factors contributing to cooking quality.

As parameters of cooking quality, these authors considered the following:

(1) Whether easily cooked or not,

(2) nature after cooking - sticky or nonsticky and

(3) taste after cooking (organoleptic quality) - starchy or nonstarchy.

Suseela *et al.* (1980) studying the utilisation of residue from tapioca starch studied the characters like starch content, crude fibre, reducing sugars and HCN as starch characteristics.

12. <u>Path analysis and correlation studies in tuber crops</u>

The method of path analysis which is a useful tool for statistical analysis of relationship between correlated variables was developed by Wright (1921). Path coefficients are equivalent to standard regression coefficients and they measure the direct influence of one variable upon another. They also permit the partitioning of the correlation coefficients into two components namely direct and indirect effects.

Magoon *et al.* (1972) studying the characters of F_1 population of some cassava cultivars showed that tuber number per plant was significantly and positively correlated with tuber yield. Positive correlations were also found to exist between tuber length, tuber girth, plant height and rind thickness. Again tuber length was positively and significantly correlated with tuber girth.

According to Thamburaj and Muthukrishnan (1976) to get higher yields in sweet potato the weight of foliage, girth of tubers and number of tubers, are the more important yield components.

Kamalam *et al.* (1977) estimated the correlation between yield and yield components and their path coefficients in sweet potato. Numbers of tubers showed positive and very high degree of correlation coefficient with the yield. Length of vine as well as vine weight showed negative correlation. It was observed that number of tubers per plant, length of petiole and weight of vine should be the criteria for selection of high yielding plant types in sweet potato.

Kamalam *et al.* (1978) reported the association of characters in seventy one selected progenies of cassava. Correlation coefficients were studied for tuber yield and five yield components viz., harvest index, number of tubers, number of nodes, weight of vegetative part, and plant height. Harvest index showed significantly negative correlation with number of nodes, weight of vegetative part and plant height. The yield was mainly dependent on harvest index, number of tubers and weight of vegetative part.

Lakshmi and Easwari Amma (1980) studied the variability and interrelationship between tuber yield and seven quantitative characters were marked out in twenty genetic stocks of *Dioscorea alata*. Tuber yield recorded positive and significant association with number of shoots, number of branches and number of leaves.

Abraham and Nair (1990) studying the correlation in lesser yams (*Dioscorea esculenta*) found that among correlation coefficients of eight characters, tuber yield was positively correlated with number of tubers, individual tuber weight and tuber length.

Materials and methods

MATERIALS AND METHODS

Sand culture experiment

A sand culture experiment was conducted to study the optimum time of potash application and to find out the visual and chemical changes in the plant when potash was not included in the nutrient solution. White sea sand (grading from 0.5 - 1.0 mm) was used for the culture. According to Hewitt (1966) sand with grading 80 - 90 per cent between 0.5 - 1.0 mm provided satisfactory medium for growth of a wide range of crops when nutrient solution was given intermittently. The selection of the sand was based on this criterion and also the good yields achieved in sandy soil areas of the State with adequate manuring.

Concrete pots of 90 cm diameter and 45 cm deep were specially prepared for this study. The inner side of the pots were painted with bituminous paint (to avoid nutrient contamination from cement). A small hole was provided at the bottom of the concrete pot which could be closed tightly with a rubber cork.

The sand was filled upto 30 cm in all pots and washed thoroughly. Washed sand was then treated with a mixture of 17 per cent hydrochloric acid and 1 per cent oxalic acid (Kanwar, 1976). The sand was again washed thoroughly with water till free from potassium. The pH of the sand was also checked which was near neutral. Hewitt (1966) had indicated that in deep pots (25-30 cm) owing to high water table, it was not necessary to water more than once daily. Further he is of the opinion that large tank cultures (40-100 lit.capacity) required change of nutrient solution every 2-4 weeks. However the loss of water by transpiration and evaporation can be made good by daily additions of water between intervals of renewal. In view of this the experimental pots were watered once daily.

Details of the sand culture experiment:

Design: C.R.D.

Replications: 3

Varieties: 2 (H-4 and H-2504)

Treatments: 9

(1) All nutrients except K (control)

(2) " " + K for 0-1½ months

(3) " " + K for 0-3 months

(4) " " + K for 0-4½ months

(5) " " + K for 0-10 months

(6) " " + K for 4½-10 months

(7) " " + K for 3-4½ months

(8) " " + K for 1½-3 months

(9) " " + K for 1½-4½ months

All the above chemicals used were of A.R. quality and a combined and concentrated stock solution was prepared (except K and Fe). This stock solution was diluted to

57.3 lit. (water retention capacity) when the desired concentration of each element was obtained. The nutrient solution was supplied at bi-weekly intervals. Potash was added to nutrient solution depending upon the treatment and during periods when potash was included in the treatment the pots were watered daily to compensate for evapotranspiration. Fig.1 shows the arrangement of the pots (Numbers show treatments, 1-9 cultivar - H-2504 and 10-18 cultivar M4).

According to Hewitt (1966) the water retention capacity of sand (grading between 0.5-1.00 cm) is about 30.2 per cent. Sand used in the present study was also found to have a retention capacity of 30 per cent.

The volume of the pot (upto 30 cm ht) = $\pi r^2 h = 3.14 \times 45 \times 45 \times 30$

i.e. = 190755 cm^3

Water retension capacity = $190755 \times \frac{30}{100}$

i.e. = 57266 cm^3

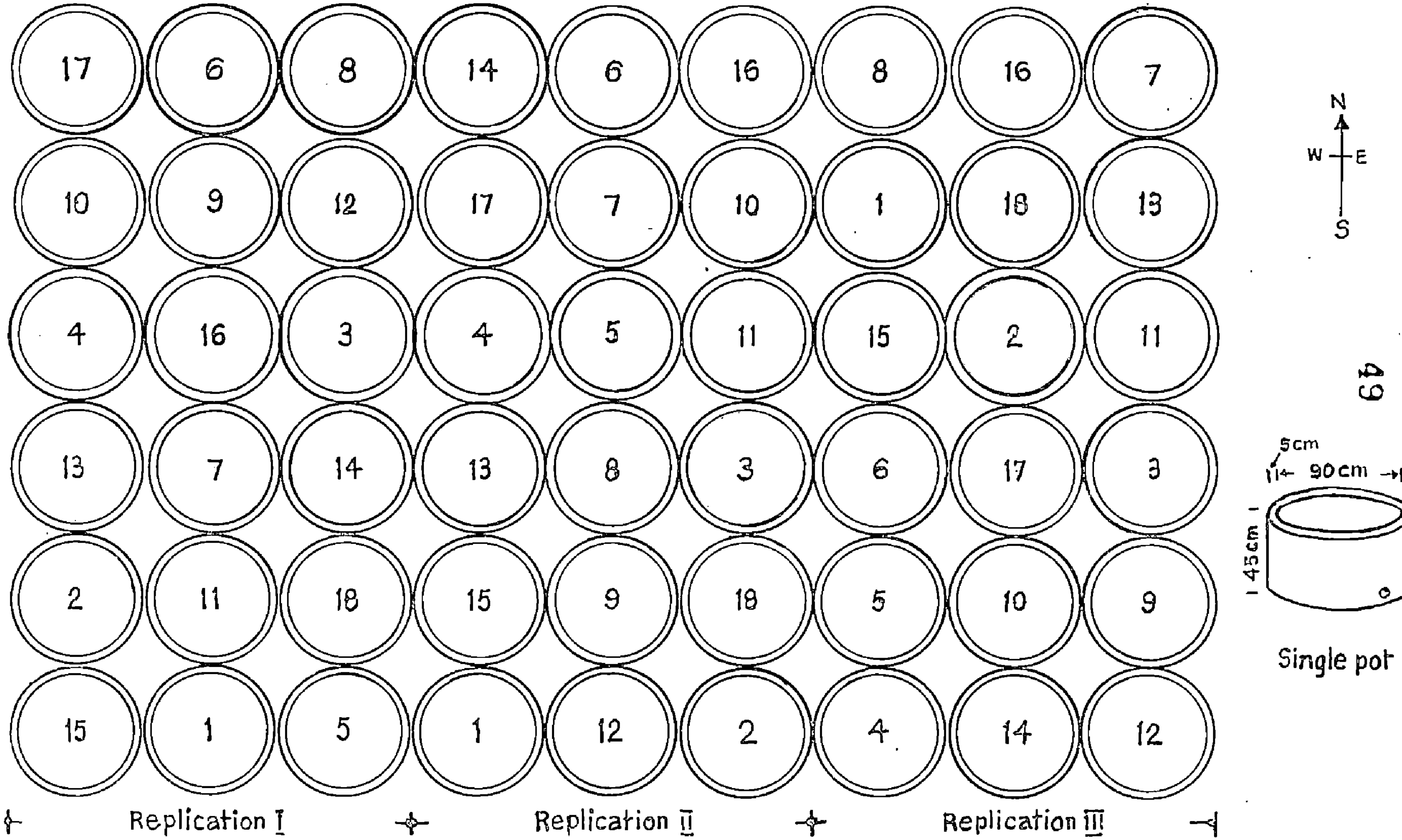
i.e. = 57.3 litres

The modified nutrient solution of Arnon and Hoagland (1940) was used for this study with the following composition.

Nutrient	g/l	millimoles/l
KNO_3	1.010	10.0
$Ca(NO_3)_2$	0.492	3.0
$NH_4\ H_2PO_4$	0.230	2.0
$MgSO_4 \cdot 7H_2O$	0.490	2.0

Fig. 1

ARRANGEMENT OF POTS FOR SAND CULTURE EXPERIMENT
(Number in each pot indicate the treatment)



Micronutrients	mg/l	micromoles/l
H_3BO_3	2.84	46.00
$CuSO_4.5H_2O$	0.08	0.32
$MnCl_2.4H_2O$	1.78	9.00
$ZnSO_4.7H_2O$	0.22	0.77
$H_2MoO_4.H_2O$	0.08	0.50
$FeSO_4.7H_2O$	0.03	1.08

The experiment was planted on 29-12-1978. One stake (healthy, disease free and cut from the middle portion of the stem), 15 cm long, was planted in the middle of each pot. The crop was harvested on 25-10-1979 after ten months.

Micro plot experiment

A microplot experiment was conducted (with four plants in each plot) after excavating the four sides of the plot upto 30 cm and paving with bricks and plastering with cement. First two crops of cassava (with guinea grass as intercrop) were planted with N and P only (@100 kg/ha each) so as to exhaust the soil potassium to the extent possible. The third crop was taken with five levels of potash. The following were the details of the experiment.

Design:	R.B.D.
Replications:	3
Plot size:	1.8 x 1.8 m
Spacing:	0.9 x 0.9 m (90 x 90 cm)
No. of plants/plot:	4

Varieties: 2 (H-2304 and M4)

Treatments: 5 (0, 50, 100, 150 and 200 kg K_2O/ha)

The layout of the experiment is shown in Fig.2. The numbers inside the plots indicate treatments (Nos. 1 to 5 for cultivar M4 and Nos. 6-10 for cultivar H-2304 with necessary levels of potash from 0 to 200 kg/ha).

First crop (H-2304 and guinea grass as intercrop) was planted on 10-4-1978 and harvested on 28-10-1978. During this period the guinea grass was cut twice, first on 26-6-1978 and the second on 28-10-1978. The second crop was planted on 30-10-1978 and harvested on 10-4-1979. The first two crops were grown only for six months each being soil exhausting crops.

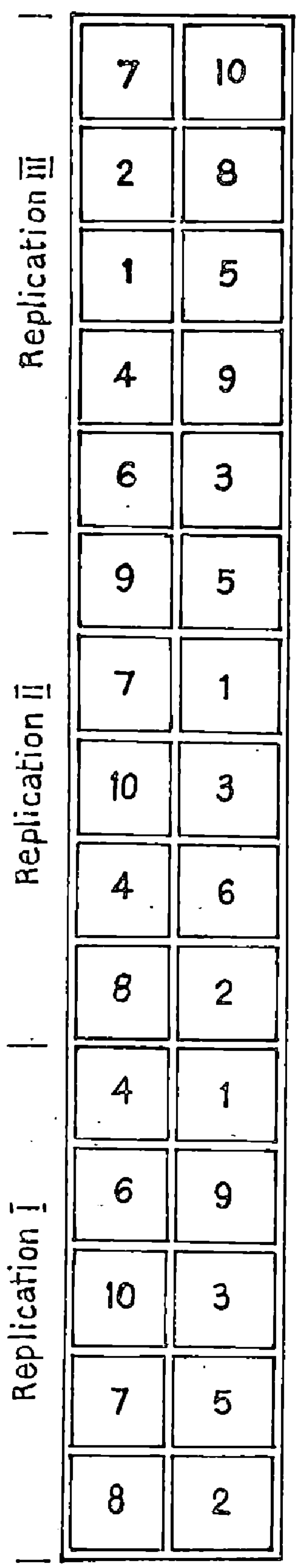
The proper experiment (third crop) was planted on 20-5-1979 after digging the plots with spade and making four mounds in each plot. The treatments were randomised in each replication. Basal application of the full dose of phosphorus (@ 100 kg P_2O_5/ha and half dose of potassium (for each treatment) and nitrogen (@ 50 kg N/ha) were given at the time of planting. On 60th day, with the first-weeding the second dose of nitrogen (@ 50 kg N/ha) and the remaining half dose of potassium for each treatment was applied. The crop was harvested after 10 months on 19-3-1980.

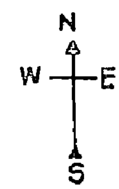
Collection and preparation of plant samples

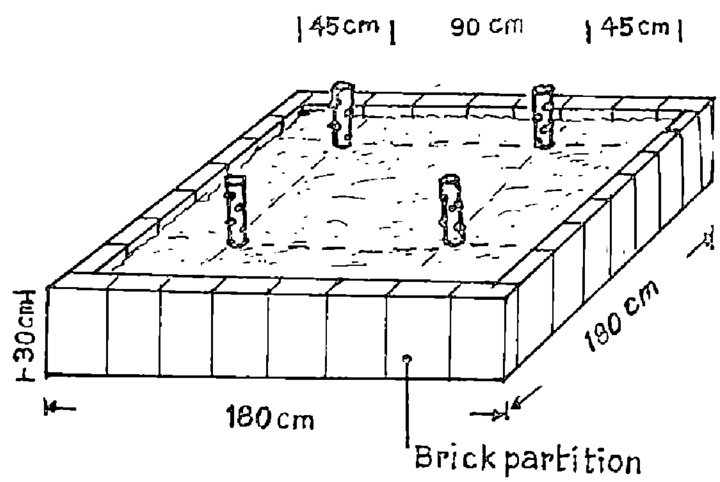
The time of sampling of plant material is largely dependent on the purpose for which it is collected. For

Fig.2

LAYOUT OF MICRO PLOT EXPERIMENT







SINGLE PLOT

(number in each plot indicates treatment) nutritional disorders, it is required to collect the samples when the plant is showing the disorder. A chemical analysis at that stage is very helpful in diagnosing the disorder. In order to study the nutrient uptake samples are to be collected at different stages of growth. For total nutrient uptake by a crop, the whole plant samples are to be collected at maturity. Sampling at this stage may give a lesser estimate of nutrient uptake because some of the older leaves might have fallen off and some nutrients like nitrogen and potassium might have been leached away by rains. Hence care was taken to collect plant samples.

Cours *et al*. (1961) studied the effect of various fertilizers on the nutrient levels in the phelloderm of the main stem in cassava. Application of N and K had a positive effect on N and K content in the phelloderm. Pushpadas *et al*. (1976) showed that the middle group of petioles served as the 'reflect' for analysis of N, P, K and Ca in cassava. They also found that the 4½ month stage was the most suitable time for foliar diagnosis. Since critical concentrations of nutrients vary with age, climatic conditions and other factors, the plant part to be analysed should be selected with care. Asher *et al*. (1980) recommended the youngest fully expanded leaf (YFEL) blades or petioles as the best indicators of nutritional status. In the present study for critical concentration, YFEL leaf blades of 4½ months stage were collected.

Taking into consideration all the above findings for chemical analysis the following modified method was adopted. The cassava stem with the leaves was arbitrarily divided into three portions viz., top, middle and bottom and leaf and stem samples were separately collected and mixed to get approximately 15-20 leaves and 50 g of stem. 50 g of tuber samples were collected from two medium sized tubers. The number of leaves shed earlier to harvest was counted from the markings on the stem. The nutrients removed by such leaves were computed.

The plant samples immediately after collection were cleaned with a piece of white cloth to remove dust and soil particles. The tuber samples were cleaned with water and then wiped. The samples were dried in air oven at 65°C (stem and tuber samples were sliced into small pieces, before drying) ground to a fine powder and used for chemical analysis. The samples were kept in clean dry polythene containers with tight lids. During collection, preparation and grinding care was taken to avoid contamination.

<u>Moisture determination</u>

Five grams of accurately weighed plant material (leaf, stem and tuber samples--sliced into small pieces, starch--powdered sample) was placed in a silica dish (previously weighed after drying in an air oven). The dish with the sample was dried in an electric oven at 105°C for

6 hours, cooled and weighed. Drying was repeated until consecutive weights agree. The percentage moisture was expressed on oven dry basis.

Determination of granule size (ISI, 1960)

A 2 per cent suspension of the starch sample was prepared in water in a test tube. From the well shaken suspension 2-3 drops were placed on a glass slide by means of a glass rod. A cover glass was placed over the drops on the glass slide excluding air bubbles in between the cover glass and the slide. The slide was examined under a compound microscope at a magnification of 500 X. An ocular micrometer was standardised earlier with a stage micrometer. With the ocular micrometer the diameter of the granules was read in microns. From ten number of observations the average was worked out.

Determination of starch (Aminoff et al., 1970)

To one gram of fresh cassava tuber (without rind) ground in a mortar with pestle, 20 ml of 2 N HCl was added and heated on a water bath for 2 hours, cooled and made up to 100 ml. This was then titrated against 10 ml of 0.05 N K_3 Fe $(CN)_6$ to which 5 ml of 2.5 N NaOH was added, using methylene blue as indicator. A blank titration was run with 0.05 N glucose solution.

<u>Calculation</u>

1 ml of 0.05 N glucose = 9.01 mg glucose

Let the blank titre value be X ml

X ml of 0.05 N glucose = X x 9.01 mg glucose

To reduce 10 ml of 0.05 N $K_3Fe(CN)_6$ = X x 9.01 mg glucose

Per cent of starch in the unknown solution = $\frac{(X \times 9.01)}{T.V.} \times \frac{100}{W} \times \frac{100}{1000} \times \frac{19}{20}$

where T.V. = titre value

X = blank titre value

W = weight of sample in g

and $\frac{19}{20}$ = factor for conversion of sugar to starch

<u>Estimation of reducing sugar</u> (Aminoff *et al.*, 1970)

To one gram of cassava tuber ground in a mortar with pestle and transferred into a conical flask added 20 ml of 90 per cent ethyl alcohol. Boiled on water bath for one hour after placing a small funnel on the mouth of the conical flask. After extraction of sugar, filtered through Whatman No.1 filter paper. To the filtrate added 10 ml of 2 N HCl and boiled on a water bath for 1/2 an hour (till all the ethanol was evaporated off). Made upto 100 ml and titrated against 10 ml of 0.05 N $K_3Fe(CN)_6$ to which 5 ml of 2.5 N NaOH was added. A blank titration was done with 0.05 N glucose solution.

Calculation

Same as for starch determination. The factor $\frac{19}{20}$ is not required.

$$\text{Per cent for reducing sugars in the sample} = \frac{(X \times 9.01)}{T.V.} \times \frac{100}{W} \times \frac{100}{1000}$$

where X = blank titre value

T.V. = titre value and

W = weight of sample taken

Estimation of HCN (Indira and Sinha, 1969)

One gram of fresh tuber sample (without rind) was homogenised with distilled water in a mortar with pestle and transferred into a 300 ml conical flask immediately (volume of homogenate being 25 ml). A Whatman No.1 filter paper strip (10 x 2 cm), soaked in alkaline sodium picrate (25 g of sodium carbonate and 5 g of picric acid powder in 1 litre of distilled water), dried and suspended under a suitable rubber cork (with a bent pin) was placed on the mouth of the flask and closed tightly. Kept overnight (18 hours) and eluted the filter paper strips in 60 ml distilled water. Absorbency was recorded in a colorimeter using green filter (515 - 550 mμ). The amount of HCN was calculated from a standard curve, drawn using standard HCN solution.

Determination of Amylose in starch (Mac Cready and Hassid, 1943)

100 mg of dried sample was ground to 60 mesh and

defatted with methanol using a centrifuge. Drove off residual methanol by dipping in a warm water bath. Transferred the dried sample to a waring blender and added 90 ml of 1 N NaOH solution and blended immediately (caking or clumping can be prevented by starting blender immediately after adding NaOH). After blending dispersed the foam by adding 5 ml ethanol and transferred to a beaker. Pipetted 10 ml of aliquot into 150 ml beaker containing 50 ml distilled water. Added 0.05 N HCl to bring the pH to 10.5. To the contents of the beaker added 2 ml of iodine solution (0.2 g iodine and 2.0 g potassium iodide in 100 ml of distilled water). Transferred the contents to a 100 ml volumetric flask and made up to the mark with distilled water. The intensity of the blue colour was read after 20 minutes at 590 mμ. Percentage of amylose was determined by reference to a standard curve drawn using standard amylose solutions.

<u>Determination of alkali number</u> (Schoch, 1964)

A 500 mg sample of starch (ground to pass through 60 mesh screen) was weighed and transferred to a clean dry round bottomed blask, closed with a one-holed rubber cork, through which a small capillary glass tube was inserted. This provided a vent for steam during the digestion and minimised the entry of CO_2. Ten ml of distilled water was added and the contents were gently swirled to wet and uniformly suspend the sample. Then 25 ml of 0.4 N NaOH solution was added while swirling the flask to ensure uniform gelatinisation and dispersion of the sample (lumping should be avoided). Finally

65 ml of boiling distilled water was added. The contents were mixed by agitation and the flask was stoppered immediately and placed in the boiling water bath and digested for 60 minutes. During digestion, the flask was swirled several times to ensure uniform mixing. At the end of 60 minutes, the flask was removed and placed in ice and water bath. To halt the alkaline degradation 75 ml of distilled water (0°C) was added and the solution transferred to a 400 ml beaker rinsing the flask several times with distilled water. The beaker was then placed on a magnetic stirrer. One ml of 0.1 per cent ethanolic solution of thymol blue was added and the solution titrated to clear yellow end point with standard acid. As blank determination 25 ml of standard 0.4 N NaOH solution in approximately 100 ml of distilled water was titrated with standard acid to thymol blue end point. The alkali number was then calculated as ml of 0.1 N alkali consumed per gram of dry starch.

$$\text{Alkali number} = \frac{(\text{Blank titre} - \text{sample titre})\ \text{ml} \times \text{acid normality} \times 10}{\text{Dry sample weight in g}}$$

Determination of gelatinization (pasting) temperature (Mac Masters, 1964)

A 0.5 per cent suspension (by weight) of the starch in distilled water was made at room temperature in a test tube. The tube was placed in a water bath at room temperature. A thermometer was suspended in the starch suspension so that it touched neither the wall nor the bottom of the test tube. The temperature of this was increased by about 0.5°C each 3 minutes. With the thermometer the suspension was gently stirred to keep the temperature uniform throughout. Care was taken to make sure that no starch stuck to the test tube walls above the level of the liquid. To remove a drop for microscopic observation, a clean pipette made of glass tubing to a medium tip was used. Used a clean, dry pipette for each removal to avoid contamination and/or change of temperature of suspension.

Samples were removed, mounted and microscopically observed at room temperature at 50°C, 55°C and at each 0.5°C increase in temperature thereafter, until gelatinisation was complete (at gelatinisation temperature of starch all birefringence was lost by all granules). This temperature was noted and recorded as gelatinisation temperature.

Determination of Viscosity (ISI, 1960)

Transferred 4 g of oven dry starch into a conical flask. Added about 25 ml of cold water and made a slurry. Lumps and clots were broken with a glass rod. Poured sufficient boiling water, with constant stirring till the amount of water added was just 200 g. Boiled the paste gently under reflux condenser for one hour and cooled to 75°C with constant stirring. Then measured the viscosity of the paste in seconds in a Red wood Viscometer at 75°C (Viscosity was expressed as that of a 2 per cent paste in seconds at 75°C).

Estimation of total potassium in soils (Jackson, 1967)

The total K in soils was determined by extraction with Na_2CO_3 fusion followed by disintegration with HCl. 0.1 g of air dried sample was transferred to a platinum crucible. Approximately 0.75 g of Na_2CO_3 was added to the sample and throughly mixed. About 0.25 g of Na_2CO_3 was then added on the top of the mixture. The crucible was first gently and then strongly heated over a bunsen burner until the melt was liquefied. Heated for 2-3 minutes more and removed the crucible from the flame. After cooling, the melt was disintegrated by addition of 30 ml of HCl and made upto 100 ml. The potassium in the made up solution was estimated flame photometrically after diluting a suitable aliquot.

Determination of reducing value (Schoch, 1964)

250 mg of starch was weighed and transferred to a round bottomed flask. 2-3 ml of benzene was added to prevent lumping. 25 ml water was added while swirling the flask to get a suspension. The flask was heated in a boiling water bath with frequent agitation until uniform dispersion or solution of the sample was achieved. To the hot solution 25 ml of alkaline ferricyanide (16.5 g of potassium ferricyanide and 22 g of sodium carbonate in 1 litre of distilled water) reagent was added. The flask was closed with a

vented rubber stopper and heated in the boiling water bath for 15 minutes with occasional agitation. The flask was then removed, cooled and 50 ml of zinc sulphate-acetic acid solution (200 ml glacial acetic acid, 70 g of potassium chloride and 20 g of zinc sulphate heptahydrate in 1 litre of distilled water) was added with care to avoid excessive frothing. Twenty ml of 20% potassium iodide was added and the liberated iodine titrated against 0.05 N sodium thiosulphate. Blank was run adding all the above reagents and titrated similarly adding starch indicator.

$$\text{Reducing value} = \frac{(\text{Blank titre} - \text{sample titre})\ \text{ml} \times \text{normality} \times 10\ \text{of thiosulphate}}{\text{Sample weight of (dry basis)}}$$

<u>Determination of swelling volume</u> (Sair and Fetzer, 1964)

Ninety ml of boiling water was added to 1 g of dry starch suspended in 10 ml of water contained in a 250 ml centrifuge tube (graduated). The centrifuge tube was closed with a rubber cork and inverted several times until the starch was completely and uniformly suspended. Then the centrifuge tube was placed in boiling water bath (with a supporting clamp) and heated for 30 minutes. Then cooled to room temperature and centrifuged at 2000 rpm for 15 minutes. By means of a glass tube attached to a suction flask, the clear supernatant was drawn off by suction. Noted the remaining volume of the gelatinous sediment. This was recorded as the swelling volume (ml per g of dry starch).

Extraction of starch (Bodenhuizen, 1964)

Depending on the quantity of the material available the peeled and washed tubers (fresh) were homogenised in a waring blendor with addition of some water. The suspension was filtered through muslin cloth immediately. Then the filtrate of starch suspension was centrifuged at 1500 rpm. The supernatant solution was discarded and the sediment dried in the air oven at 60°C for 6 hrs. Since the dried product will undergo physical changes during storage it was not stored for a long time.

Determination of crude fibre (Chopra and Kanway, 1978)

Took 5 g of dried and powdered sample in a 400 ml beaker marked at 200 ml level. Added 200 ml of 1.25 per cent sulphuric acid and boiled for half an hour. Filtered through muslin cloth. Washed with water to render it free from acid. Transferred the residue to the beaker and then added 200 ml of 1.25 per cent caustic soda and boiled for half an hour. Filtered and washed it free from alkali using in turn hot water, 1 per cent HNO_3 and hot water respectively. Transferred the residue to a weighed dish and dried it to a constant weight at 100°C. Ignited the residue to get ash and found the weight again. The loss in weight due to ignition was equal to crude fibre. Expressed this as percentage.

Determination of total nitrogen in plant (H_2O_2 oxidation method, Jackson, 1967)

Took 0.1 g of plant material (dried and finely ground) in a clean and dry boiling tube. Added 2 ml of concentrated sulphuric acid and heated on a hot plate gently, after keeping the tubes in a wire basket. When warm added hydrogen peroxide (approximately 1 ml of 100 volumes) slowly through the sides using a pipette and digested for 1 hour, raising the temperature of the hot plate. Hydrogen peroxide was added when the contents turned brown and repeated this till the solution became clear. Stopped digestion, cooled and diluted to 100 ml in a volumetric flask. Suitable aliquots (1 ml) were taken in Nessler tubes of 10 ml capacity, added 2 ml of 1 N NaOH, 1 ml of Nessler's reagent and 6 ml of distilled water. Mixed thoroughly and read the colour in a colorimeter using blue filter (425 mμ). Noted the ppm of N from a standard curve and calculated the per cent of nitrogen in the sample taken.

Determination of total phosphorus in soil and plant tissue (Vanado molybdophosphoric yellow colour method Jackson, 1967)

Took 10 ml aliquot (from tri acid digest in the case of both plant tissue and soils in a 25 ml volumetric flask. Added two drops of 2-4 dinitrophenol and then added liquor ammonia drop by drop till the colour changed to yellow. Then added 1 N nitric acid drop by drop till the yellow colour just disappeared. To this solution added 5 ml of vanadate reagent (HNO_3-vanadate-molybdate reagent) and made up to 25 ml with distilled water. Shook thoroughly and read in a colorimeter using blue filter (490 mu) after 10 minutes. The ppm of phosphorus in the solution was read from a standard curve from which the phosphorus content in the sample was computed.

Determination of available nitrogen in soil (Alkaline permanganate method. Subbiah and Asija, 1956)

Twenty gram of soil was taken in a 1 litre distillation flask. 20 ml of water was added followed by 100 ml each of freshly prepared 0.32% potassium permanganate and 2.5% sodium hydroxide. Placed the flask in the distillation apparatus and dipped the end of the delivery tube in the boric acid solution. The contents were distilled and ammonia evolved (about 100 ml distillate) was collected in a 250 ml conical flask containing 4% boric acid solution to which five drops of mixed indicator (0.1 g of methyl red and 0.5 g of bromo-cresol green in 100 ml ethyl alcohol) was added.

Titrated the boric acid solution with 0.1 N sulphuric acid till the blue colour disappeared and turned to pink.

Calculation

Weight of soil taken	= 20 g
Volume of 0.1 N sulphuric acid used	= X ml
Weight of nitrogen in 20 g soil	= X x 0.1 x 0.014 g
Percentage of nitrogen	$= \frac{X \times 0.1 \times 0.014 \times 100}{20}$

Determination of available phosphorus in soil
(Bray and Kurtz, 1945)

Weighed 5 g of soil (air dried and 2 mm sieved) into a 250 ml conical flask. Added 50 ml of Bray's extractant No.1 (0.03 N ammonium fluoride in 0.025 N hydrochloric acid). Shook for five minutes in a reciprocating shaking machine and filtered through Whatman No.1 filter paper. Took 5 ml of the aliquot in a 25 ml volumetric flask. Added 5 ml of molybdate reagent (15 g of ammonium molybdate in 300 ml distilled water + 350 ml 10 N hydrochloric acid, diluted to 1 litre) and diluted to 20 ml with distilled water. Added 1 ml of stannous chloride solution (10 g of stannous chloride in 25 ml conc. hydrochloric acid 0.5 ml of this solution diluted to 66 ml with water) shook and made upto 25 ml. Simultaneously prepared a blank. Read the intensity of colour in a colorimeter using red filter (660 mu). Found the phosphorus content of the solution from a standard curve and calculated the available phosphorus in the soil sample.

Calculation

$$\text{Available P} = \frac{\text{ppm} \times 25 \times 50 \times 2240000}{5 \times W \times 1000000} \text{ kg/ha}$$

where W = weight of sample taken and

ppm = ppm P read from the standard curve

Determination of potassium in soils and plant tissues
(Jackson, 1967)

Exchangeable potassium from 5 g of soil was extracted with 1 N ammonium acetate (100 ml) after shaking for

10 minutes in a reciprocating shaking machine. Filtered through Whatman No.1 filter paper and the clear filtrate was fed directly into the flame photometer.

For plant tissues wet oxidation with tri acid mixture was adopted (the ratio of nitric acid: sulphuric acid: Perchloric acid being 10:1:4). To 1 g of dried and powdered sample 5 ml of tri-acid mixture was added slowly through the sides of the boiling tube. After frothing had subsided, the boiling tubes were placed in a sulphuric acid bath and digested on a hot plate kept in a fume chamber. The digestion was continued till the contents in the boiling tubes become clear and fumes subsided. After cooling, the extract was diluted to 100 ml in a volumetric flask. 5 ml of this extract was again diluted to 100 ml and read in a flame photometer.

Potassium in the extract (as ppm) was read from a standard curve and the potassium content in the sample was recorded taking into consideration the dilution made.

<u>Yield attributes</u>: Number of tubers per plant

The tubers from the observational plants were separated and counted and the average number per plant was calculated.

<u>Length of tubers</u>

Length of medium sized tubers was measured and the average taken.

<u>Girth of tubers</u>

Girth measurements were recorded from those tubers which were used for length measurements. The maximum girth of the tubers at the middle portion was recorded and average value was calculated.

<u>Girth of stem</u>

Maximum girth of stem at the point of formation from the mother stem was recorded and the mean calculated.

<u>Utilization index</u>

The ratio of root weight to top weight (stem and leaves) was calculated for each treatment.

<u>Tuber yield</u>

After carefully pulling out the plants from the soil, the tubers were separated, cleaned and the fresh weight recorded. Average weight per plant was then calculated.

<u>Cooking quality</u>

The cooking quality of tuber was assessed by a taste panel. Tubers from different levels of potassium application was tested for cooking quality (Prema et al., 1975). A random sample of about 2 kg fresh tubers was collected from different levels of potash application, derinded, cut into pieces 3-5 cm length, washed clean and cooked for 30 minutes till the flesh was soft. The taste was assessed on a discrete scale with five points. The best taste was assessed as sweet and was allotted a score of 4. The other scores in decreasing order of taste were watery sweet (3), starchy (2), bitter (1) and watery bitter (0).

Results

RESULTS

SAND CULTURE EXPERIMENT

Table 5 presents the data on the yield of tubers of two varieties K-2304 (V_1) and M-4 (V_2) under different treatments with potassium as already described under materials and methods. Being a sand culture experiment with nutrient solution, the treatments are in respect of duration of supply and critical period of supply of potash to the plant rather than in terms of quantities. From the results it can be clearly seen that the maximum yield obtained is for treatment number 4 (T_4) wherein potassium was supplied from the time of planting upto 4½ months.

Table 5. Sand culture experiment - Yield (kg/plant)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	1.42	2.33	3.13	6.92	3.31	2.05	3.35	2.72	2.57	3.09
V_2	1.38	1.92	2.75	4.08	3.15	2.17	3.63	2.03	2.20	2.59
Mean	1.40	2.13	2.93	5.50	3.23	2.11	3.49	2.38	2.38	

C.D. at 5% for V = 0.137

" T = 0.291

" V x T = 0.411

Treatments T_7 and T_3 in which potassium was supplied during the period 3-4½ months only and 0-3 months only come next in order. Treatment in which potassium was fed only for 1½-3 and 1½-4½ months recorded still lower yields. Starving the plants of potassium upto 4½ months and subsequent nutrition upto full period of growth viz., T_6 recorded low yields, though it was superior to the no potassium control (T_1). The variety K-2304 (V_1) recorded significantly higher yields than the variety K-4. This was found to be so in almost all the treatments except in T_6 and T_7.

Table 6 presents data on the number of tubers per plant.

Table 6. Sand culture experiment - Number of tubers/plant

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	8.33	13.00	16.00	24.00	14.67	12.33	14.67	11.67	10.33	13.89
V_2	9.00	11.00	13.00	16.33	20.33	12.00	10.33	9.33	9.33	12.29
Mean	8.67	12.00	14.50	20.17	17.50	12.17	12.50	10.50	9.83	

C.D. at 5% for V = 0.789
" T = 1.673
" V x T = 2.366

The results of the sand-nutrient culture experiment show that the period at which potassium is supplied to the plants through nutrient solution and the growth phase of the plant synchronising with this period has significantly affected the number of tubers per plant. Thus plants which have received potassium nutrition from 0-4½ months period (T_4) have registered the highest number of tubers (20.2 tubers/plant) compared to other treatments, in general. This is significantly greater than those which have received potassium nutrition during the entire period of growth viz., 0-10 months (T_5), which itself is superior to those which have received potassium nutrition for the period 0-3 months (T_3). Other treatments fall into three groups with lesser number of tubers than the above mentioned three treatments. Thus T_7, T_6 and T_2 which are themselves at par register tuber numbers ranging from 12.5 to 12.0, treatment T_8 with a significantly lower tuber number than these three treatments viz., 10.5 and T_9 and T_1 registering tuber numbers in the range of 8.6 to 9.8. The control with zero potash (T_1) records minimum tuber number viz., 8.6 Between the two varieties V_1 (H-2304) and V_2 (M-4), the number of tubers are significantly higher in the case of the former. Variety-treatment interaction is significant in respect of tuber numbers in treatments T_3, T_4, T_5, T_7 and T_8.

Table 7 presents data on the average length of tubers per plant. From the data it is seen that the nine treatments fall into five groups which are significantly different from one another. Thus treatments involving potassium nutrition from 0-4½ months (T_4) and treatment involving potash nutrition for the entire duration of the crop (T_5) are significantly different from each other and from the other treatments, the former recording the maximum tuber length of 36.6 cm. Treatments T_7 and T_8, involving potash nutrition for 3-4½ months only (T_7), 1½-3 months only (T_8) and 0-3 months only (T_3) are on a par with respect to tuber length, but record significantly lesser length than the earlier mentioned two treatments viz., T_4 and T_5. The treatment involving potash nutrition for a period of 4½-10 months and the period

0-1½ months (T_6 and T_2) are on par, but T_6 is not significantly different from T_5. Treatments T_9 and T_1 record the lowest tuber lengths and are on a par with each other and are significantly

Table 7. Sand culture experiment - Length of tubers (cm)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	25.6	27.9	31.2	40.6	35.5	29.4	30.8	31.6	25.8	30.9
V_2	24.7	26.6	27.7	33.0	31.0	27.7	29.1	27.8	26.4	28.2
Mean	25.2	27.3	29.5	36.8	33.3	28.5	29.9	29.7	26.1	

C.D. at 5% for V = 0.724
" T = 1.535
" V x T = 2.171

lower than T_2. In respect of length of tuber, variety V_1 (H-2304) recorded significantly greater length than variety V_2 (M-4). This is recorded in all treatments except T_9. The variety-treatment interaction is significant in treatments which have included potash nutrition for different periods viz., 0-3, 0-4½, 4½-10 and 0-10 months respectively.

Table 8 presents data on the average girth of tubers per plant which is found to fall into seven groups. The most significant results is that the plants which received potash nutrition for 0-4½ months (T_4) and plants that received K nutrition for the entire period of 0-10 months (T_5) have recorded significantly greater mean girth of tubers than the rest of the treatments. Treatment T_1 viz., control, with no added potassium in the nutrient solution throughout the growth period recorded the lowest girth of tubers with the remaining treatments occupying intermediate positions.

Table 8. Sand culture experiment - Girth of tubers (cm)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	10.7	13.0	15.3	17.1	16.1	13.3	15.2	15.5	14.8	14.6
V_2	10.3	12.1	12.9	15.2	14.1	12.9	13.9	13.1	11.6	12.9
Mean	10.5	12.6	14.1	16.2	15.1	13.1	14.6	14.3	13.2	

C.D. at 5% for V = 0.283
" T = 0.600
" V x T = 0.849

Variety V_1 (H-2304) is significantly superior to V_2(M-4) in recording greater girth of tubers. Treatment-variety interaction is significant and greater girth have been recorded in variety V_1 in all the treatments.

The data on mean height of plants is presented in table 9. From the results it is clear that the duration of potash nutrition in the sand culture experiment (viz., treatments), varieties and varietal-treatment interactions are significant. Treatments involving potash nutrition for the period 0-4½ months (T_4), 0-3 months (T_3) 0-10 months (T_5) and 1½-4½ months (T_3) are significantly superior to other treatments and differ from each other in a decreasing order.

Control treatment with no added potassium (T_1) and plants which received potash for 3-4½ months only (T_7) recorded the lowest height.

Table 9. Sand culture experiment - Height of plants (cm)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	100.4	142.1	151.9	176.0	163.0	123.1	104.0	139.5	144.9	138.2
V_2	121.6	132.9	165.1	170.5	152.1	147.4	103.2	138.2	141.6	141.3
Mean	111.0	137.5	158.5	173.5	157.6	135.3	103.6	138.7	142.7	

C.D. at 5% for V = 1.442
,, T = 3.060
,, V x T = 4.327

Variety M-4 records significantly higher plant height than variety H-2304 in general, though there are some treatments where M-4 has recorded a lower height than H-2304. There are two treatments where it has recorded significantly lower plant heights than H-2304. These are the two treatments where potash has been given only for 0-1½ months (T_2) and for 0-10 months (T_5).

Table 10 presents average girth of stem at the base. Duration of potash nutrition viz., treatments, variety and V x T interactions are significant with respect to the girth of stem. Treatments involving potash nutrition for the periods 0-4½ months (T_4), 1½-3 months (T_8), 0-10 months (T_5) and 0-3 months (T_3) are significantly superior from the remaining treatments including control, significantly different from each other and in a descending manner. The control recorded significantly the lowest value compared to all other treatments. Variety H-2304 (V_1) records significantly higher stem girths except in T_7.

Table 10. Sand culture experiment - Girth of stem (cm)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	5.9	7.9	9.2	10.5	9.7	7.6	6.8	10.2	8.0	8.4
V_2	5.3	6.8	7.6	9.0	8.2	7.5	9.0	8.0	7.5	7.6
Mean	5.6	7.4	8.4	9.8	8.9	7.4	7.9	9.1	7.7	

C.D. at 5% for V = 0.140
" T = 0.315

Table 11 presents data on the average length of petiole at the time of harvest. The data indicate that the duration of potash nutrition (viz., treatments), variety and V x T interaction significantly affect the length of leaf petiole. Treatments involving potash nutrition for 0-4½ months (T_4) and 0-10 months (T_5) are significantly superior to the other treatments including control, besides being significantly different from one another and in a descending manner. The control viz., T_1 is significantly the lowest, the remaining treatments (T_3, T_7, T_8, T_6, T_9 and T_2) occupying intermediate values in a descending order between the two extremes.

Variety V_1 (M-2304) is superior to variety V_2(M-4) in respect of leaf petiole length.

Table 11. Sand culture experiment - Length of petiole (cm)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	12.0	21.7	30.7	36.0	34.4	23.3	22.5	24.6	20.9	25.1
V_2	16.0	19.5	20.6	23.2	20.5	21.7	28.9	24.5	20.7	21.7
Mean	14.0	20.6	25.7	29.6	27.5	22.5	25.7	24.5	20.8	

C.D. at 5% for V = 0.341

" T = 0.724

" V x T = 1.025

Table 12 presents data on total number of leaves produced in the sand culture experiment with nutrient solution. From the results it can be seen that different periods of nutrition with potash through nutrient solution in sand culture experiment (viz., treatments), varieties and V x T interaction is significant in the production of leaves, during the duration of the crop period of ten months.

Nutrition of the crop with potash, from 0-4½ months (T_4) gave the highest leaf number. However this was found to be on par with the leaf number produced in treatments involving nutrition with potash for 0-3 months (T_3), 1½-3 months (T_8), 1½-4½ months (T_9) and 0-10 months (T_5). Control treatment (T_1) as well as treatments involving supply of potash beyond 4½ months upto 10 months (T_6) gave significantly lower leaf number.

Table 12. Sand culture experiment - Total number of leaves/plant

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	120.0	149.7	171.0	229.3	211.7	146.0	156.0	192.3	187.0	173.7
V_2	103.0	171.0	232.3	185.3	159.0	140.3	145.3	191.7	196.3	169.4
Mean	111.5	160.4	201.7	207.3	185.4	143.2	150.7	192.0	191.7	

C.D. at 5% for V = 8.342
" T = 17.696
" V x T = 25.027

In general variety V_1 (H-2304) produced significantly greater number of leaves than variety V_2 (H-4). The V x T interaction is significant only in T_4 and T_5 and conforming to the general trend of higher leaf number for H-2304 while for treatment T_3, it is significant but with a reverse trend.

Table 13 presents the data on mean number of leaves retained at the time of harvest. The data reveals that period of potash nutrition (treatments) is significant. The number of leaves retained (expressed as per cent of total number of leaves) is found to be highest in T_4 and T_5 viz., 0-4½ months and 0-3 months supply of potash and lowest in the control treatment (T_1).

Variety V_1 (H-2304) and variety V_2 (H-4) are not significantly different with respect to the number of leaves retained.

Table 13. Sand culture experiment - Number of leaves retained (%)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	32.5	38.1	51.2	70.5	29.6	40.2	35.1	38.1	41.2	41.8
V_2	33.9	30.4	36.3	68.9	42.3	41.1	38.7	47.8	44.0	43.2
Mean	33.2	34.3	43.8	69.7	35.9	40.7	36.9	42.9	42.6	

C.D. at 5% for T = 3.929

Table 14 presents data on number of leaves shed (expressed as per cent of total number of leaves) during the entire growth phase of ten months of both the varieties under different periods of potash nutrition in the sand culture experiment.

Table 14. Sand culture experiment - Number of leaves shed (%)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	67.5	61.9	48.8	29.5	70.4	59.8	64.9	61.9	58.8	58.2
V_2	66.1	69.6	63.7	31.1	57.7	58.9	61.3	52.2	56.0	56.8
Mean	66.8	65.8	56.3	30.3	64.1	59.4	63.1	57.1	57.4	

C.D. at 5% for T = 16.924

From the table it can be seen that in treatment involving zero potash nutrition (T_1), the per cent of leaf fall is higher than in all other treatments. Treatment which received potash for 0-4½ months (T_4) recorded the lowest leaf fall. In treatments where potash was fed for 0-1½ months (T_2), 0-10 months (T_5), 3-4½ months (T_7), 4½-10 months (T_6), 1½-4½ months (T_9), 1½-3 months (T_8) and 0-3 months (T_3) occupy intermediate values and in a descending order.

In variety V_1 (K-2304) leaf fall is greater than in variety V_2 (K-4), but they are not significantly different.

Table 15 presents data on the variation of dry matter content of flesh in tuber as influenced by the supply of potassium for different periods in the sand culture experiment. The dry matter is maximum in the treatment in which plants received potash for 0-4½ months (T_4). This treatment is significantly superior to the remaining treatments. Dry matter is minimum in the control where no potash was given. Treatments receiving potash nutrition for the entire period of growth i.e. 0-10 months (T_5) comes next to T_4. Other treatments fall into three groups:

Table 15. Sand culture experiment - Dry matter of flesh in tuber (%)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	36.15	36.93	37.66	38.66	37.66	37.48	36.53	36.39	36.08	37.06
V_2	35.28	36.72	37.60	39.52	38.60	37.76	36.67	36.19	37.34	37.30
Mean	35.71	36.83	37.63	39.09	38.13	37.62	36.60	36.29	36.71	

C.D. at 5% for V = 0.088

" T = 0.187

" V x T = 0.265

(i) those receiving potash for 0-3 months (T_3) and for 4½-10 months (T_6), (ii) 0-1½ months (T_2) and 1½-4½ months (T_9) and (iii) 1½-4½ months (T_9) and 3-4½ months (T_7), which are significantly different from each group and in a descending order.

Variety M-4 (V_2) is significantly superior to variety H-2304 (V_1) in respect of dry matter content of flesh in the tuber. V x T interaction is also highly significant.

The variation in dry matter content of rind under different periods of potash nutrition in the sand culture experiment is presented in table 16. The dry matter content of rind is also maximum in the treatment in which plants received potash for 0-4½ months only (T_4). But this is not significantly different from the treatment in which potash was supplied for 0-3 months only (T_3). Treatments involving potash nutrition for the entire growth period (T_5), for 4½-10 months only (T_6) and 3-4½ months only (T_7) are not significantly different, but in a descending order.

Table 16. Sand culture experiment - Dry matter content in rind (%)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	15.41	15.00	17.32	17.03	16.82	16.52	16.35	15.82	15.46	16.28
V_2	14.83	15.24	16.59	17.30	16.72	16.53	16.37	15.47	15.35	16.04
Mean	15.12	15.12	16.96	17.67	16.77	16.53	16.36	15.64	15.40	

C.D. at 5% for V = 0.365
" T = 0.774
" V x T = 1.095

Again potash nutrition for 3-4½ months (T_7) and 1½-3 months (T_3) have no significant difference so far as dry matter of rind is concerned. Plants receiving potash for 1½-3 months (T_8), 1½-4½ months (T_9), 0-1½ months (T_2) and zero potash (control i.e T_1) have similar effects, but in a descending order.

The variety M-2304 (V_1) records slightly higher per cent of dry matter but is not significantly superior to variety M-4 (V_2).

Table 17, presents data on the rind content of tubers under various durations of potassium nutrition in the sand culture experiment. In the zero potash (T_1) rind per cent is maximum and in treatment T_5 where plants received potash for 0-4½ months only, it is minimum. 1½-3 months (T_8) and 1½-4½ months (T_9) record the second higher rind per cent in the descending order.

Table 17. Sand culture experiment - Rind per cent

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	14.95	14.31	13.75	13.26	14.34	14.56	14.77	15.00	14.80	14.41
V_2	15.11	14.85	14.59	13.56	13.88	14.04	14.48	14.88	15.02	14.49
Mean	15.03	14.58	14.16	13.41	14.11	14.30	14.63	14.94	14.91	

C.D. at 5% for V = 0.044
" T = 0.093
" V x T = 0.131

These are closely followed by the treatments involving potash nutrition for 3-4½ months (T_7) and 0-1½ months (T_2) which are themselves in a descending order and are not significantly different from each other, followed by T_6 (4½-10 months potash application). Treatments in which potash was supplied for 0-3 months (T_3) and 0-10 months (T_5) are not significantly different but are in a descending order. The minimum per cent of rind is recorded by treatment T_4, where the plants received potash during 0-4½ months only.

The rind per cent in variety V_1 (M-2304) is significantly lower than variety V_2 (M-4).

Table 18 presents data on the variation of fibre content in the tuber due to supply of potassium for different durations as treatment in the sand culture experiment. Control treatment (T_1) in which no potash has been added records maximum fibre content, but is not significantly different from treatment T_8, where plants received potash from 1½-3 months. Treatment which received potash from 0-4½ months (T_4) records minimum fibre content, which is similar to plants receiving potash from 0-3 months (T_3). Other treatments come in between these in respect of fibre content. Treatments which received potash for 4½-10 months (T_6), 3-4½ months (T_7) and 1½-4½ months (T_9) are not significantly different but are in a descending order.

Table 18. Sand culture experiment - Fibre content in tuber (%)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	2.01	1.95	1.89	1.87	1.94	1.96	1.96	1.94	1.99	1.94
V_2	1.85	1.74	1.71	1.70	1.79	1.85	1.84	1.89	1.94	1.81
Mean	1.93	1.85	1.80	1.78	1.87	1.91	1.90	1.92	1.96	

N.S.

Treatments receiving potassium for the entire period of growth i.e. 0-10 months (T_5) and 0-1½ months (T_2) come still further in the descending order.

Fibre content in variety V_1 (M-2304) is significantly higher than in variety V_2 (M-4).

Table 19 presents data on the starch content of tubers (per cent on fresh weight basis) due to different durations of potash application in the sand culture experiment. The treatment which received potash for 0-4½ months (T_4) records maximum starch content, but it is not significantly superior to plants which received potash for 0-10 months (T_5). Treatment T_3 which received potash for 0-3 months comes next in descending order.

Table 19. Sand culture experiment - Starch content (%) on fresh weight basis)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	26.20	27.90	28.20	29.97	29.47	27.83	28.27	27.93	27.70	28.16
V_2	26.77	27.60	28.60	29.43	29.87	26.80	27.60	27.60	28.30	28.03
Mean	26.48	27.75	28.40	29.70	29.67	27.32	27.93	27.77	28.00	

C.D. at 5% for V = 0.186

" T = 0.394

" V x T = 0.557

Treatments receiving potash for 1½-4½ months (T_9) and 3-4½ months (T_7), 1½-3 months (T_8) and 0-1½ months (T_2) record still lower values of starch content in descending order. Treatments which received potash nutrition for 4½-10 months (T_6) and zero potash (T_1) are recording still lower starch contents in descending order. There is no significant difference between T_2 and T_6 i.e. potash nutrition for 0-1½ months and 4½-10 months.

There is no significant difference between varieties V_1 (H-2304) and V_2 (M-4) as far as starch content is concerned.

Table 20 presents the reducing sugar content as influenced by different durations of potash application in the sand culture experiment. The treatment which received potash from 0-4½ months (T_4) records maximum reducing sugar content which is significantly superior to other treatments.

Table 20. Sand culture experiment - Reducing sugar content (% on fresh weight basis)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	1.46	1.69	1.83	1.98	1.95	1.78	1.79	1.86	1.96	1.81
V_2	1.62	1.66	1.77	1.97	1.88	1.72	1.68	1.75	1.85	1.76
Mean	1.54	1.68	1.80	1.98	1.91	1.75	1.74	1.80	1.91	

C.D. at 5% for V = 0.013
,, T = 0.028
,, V x T = 0.040

The treatment with zero potash records minimum reducing sugar content. Other treatments come in between these two extremes. Those treatments receiving potash from 0-10 months (T_5) and 1½-4½ months (T_9) not significantly different from each other constitute one group. The second group consists of treatments receiving potash for 0-3 months (T_3) and 1½-3 months (T_8) which are also not significantly different from one another. The third group in descending order consists of treatments with periods of potash nutrition for 4½-10 months (T_6) and for 3-4½ months (T_7). Treatment T_2 receiving potash nutrition from 0-1½ months records less reducing sugar than the above groups but is superior to zero potash (T_1).

Between the varieties, H-2304 (V_1) is having significantly higher reducing sugar content than H-4 (V_2).

Table 21, presents data on the amylose content of starch under different durations of potash nutrition in a sand culture experiment. Application of potash for 0-4½ months (T_4) records maximum amylose content, which is significantly superior to all other treatments. The treatment receiving potassium nutrition for 0-10 months (T_5) and that receiving potassium from 0-3 months (T_3) come next in descending order. The treatment in which potash nutrition was given for 4½-10 months (T_6) and those receiving potash for 3-4½ months (T_7) are not significantly different from each other and are in descending order.

Table 21. Sand culture experiment - Amylose content of starch (%)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	20.40	20.83	20.94	21.19	20.82	20.75	20.69	20.58	20.62	20.77
V_2	28.05	28.34	28.57	29.05	28.94	28.80	28.62	28.45	28.27	28.58
Mean	24.27	24.59	24.81	25.12	24.88	24.78	24.65	24.52	24.45	

C.D. at 5% for V = 0.034

" T = 0.072

" V x T = 0.102

Treatments which received potassium nutrition for 0-1½ months (T_2) for 1½-3 months (T_8) and for 1½-4½ months (T_9) are not significantly different and are in the descending order. The minimum amylose content is recorded by the treatment receiving zero potash (T_1).

The amylose content in variety V_2 (M-4) is significantly higher than in variety V_1 (H-2304). The V x T interaction is highly significant.

From table 22, it can be seen that there is variation in the granule size of starch under different durations of potash nutrition in the sand culture experiment. The treatment T_4, which received potash nutrition for 0-4½ months records the maximum granule size which is significantly superior to other treatments.

Table 22. Sand culture experiment - Granule size of starch (in μ)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	21.0	22.8	25.8	35.0	29.2	26.2	23.5	25.6	25.4	26.2
V_2	32.3	33.5	33.9	37.9	35.6	35.1	34.8	36.1	36.4	35.1
Mean	26.7	28.2	29.9	36.5	32.4	30.7	29.2	30.9	31.4	

C.D. at 5% for V = 0.571
" T = 0.765
" V x T = 1.112

The treatment receiving potassium for 0-10 months (T_5) comes next to T_4. Treatments which received potash nutrition for 1½-4½ months (T_9) and 1½-3 months (T_8) record still lower granule size in descending order but are not significantly different from each other. Potassium nutrition for 1½-3 months (T_8) is again not significantly different from the treatment receiving potassium for 4½-10 months (T_6). Potash nutrition for 0-3 months (T_3) and 3-4½ months (T_7) come next in descending order and are not significantly different from each other. The last two treatments in the descending order are T_2, receiving potash nutrition for 0-1½ months and T_1, with zero potash respectively.

Between the varieties, M-4 (V_2) is significantly superior to H-2304 (V_1) as far as granule size is concerned. The V x T interaction is highly significant.

Table 23, presents alkali number of starch under different durations of potash nutrition in the sand culture experiment.

Table 23. Sand culture experiment - Alkali number of starch (ml of 0.1 N NaOH)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	7.3	7.4	7.5	7.7	7.6	7.6	7.5	7.4	7.3	7.5
V_2	8.0	8.2	8.4	8.7	8.6	8.5	8.5	8.4	8.4	8.4
Mean	7.7	7.8	8.0	8.2	8.1	8.1	8.0	7.9	7.9	

C.D. at 5% for V = 0.039
" T = 0.068
" V x T = 0.096

Treatment T_4, receiving potash nutrition for 0-4½ months records maximum alkali number which is significantly higher than all other treatments. Potash nutrition for 0-10 months (T_5) and 4½-10 months occupy the next lower positions respectively. Treatments receiving potassium from 3-4½ months (T_7), 0-3 months (T_3) and 1½-3 months (T_8) are not significantly different from each other but are in the descending order. Those treatments which received potash nutrition for 1½-4½ months (T_9) and 0-1½ months (T_2) occupy the next two positions in decreasing order followed by zero potash (T_1) recording the minimum alkali number.

Among the varieties M-4 (V_2) records significantly higher alkali number than H-2304 (V_1). The V x T interaction is highly significant.

Table 24 presents data on the pasting temperature of starch under different durations of potassium nutrition in the sand culture experiment. Application of potassium for 0-4½ months (T_4) records maximum pasting temperature and it is significantly higher than all other treatments. Treatments receiving potash nutrition for 0-10 months (T_5), 4½-10 months (T_6), 0-3 months (T_3), 3-4½ months (T_7), 1½-3 months (T_8), 0-1½ months (T_2), 1½-4½ months and zero potash (T_1) are in the decreasing order and are significantly different from each other.

Table 24. Sand culture experiment - Pasting temperature (in °C)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	56.2	57.3	58.2	60.3	59.2	59.0	58.2	58.0	57.2	58.2
V_2	65.2	66.3	67.2	68.3	68.0	67.0	66.2	65.8	65.8	66.8
Mean	60.7	61.8	62.7	64.3	63.6	63.2	62.6	62.1	61.5	

C.D. at 5% for V = 0.141

" T = 0.290

" V x T = 0.422

The variety M-4 (V_2) is significantly higher than variety H-2304 (V_1) as far as pasting temperature is concerned. The V x T interaction is highly significant.

Table 25 presents data on the viscosity of starch under different durations of potash nutrition in the sand culture experiment. Treatment T_4, which received potash nutrition for 0-4½ months, records maximum viscosity, but it is not significantly different from those treatments receiving potassium for 0-3 months (T_3) and for 0-10 months (T_5) which are in the descending order. Again T_5 and T_6 (4½-10 months of potash application) are not significantly different from each other and are in the decreasing order. The next treatments in the descending order are those receiving potash nutrition for 1½-3 months (T_8), 0-1½ months (T_2) and 3-4½ months (T_7).

Table 25. Sand culture experiment - Viscosity (2% starch paste in seconds)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	54.0	54.7	55.7	57.0	56.7	55.7	55.0	56.0	55.3	55.6
V_2	55.0	55.7	57.7	57.3	56.7	56.0	55.3	55.3	54.3	55.9
Mean	54.5	55.2	56.7	57.2	56.7	55.8	55.2	55.7	54.8	

C.D. at 5% for V = 0.260
,, T = 0.552
,, V x T = 0.781

The last two treatments in the decreasing order are those receiving potash nutrition for 1½-4½ months (T_9) and zero potash (T_1). Here again there is no significant difference between the two treatments.

Table 26 presents data on the swelling volume of starch under different durations of potash application in the sand culture experiment. From the results it can be seen that the treatments where the duration of potash nutrition was for 0-4½ months (T_4), 0-3 months (T_3) and 0-10 months (T_5) are on par though the first treatment (T_4) records the highest swelling volume. However these values are significantly greater than other treatments. Potassium nutrition for 4½-10 months (T_6) and 3-4½ months (T_7) are not significantly different from each other and are in the descending order. The next treatment in the decreasing order is T_2 which received potassium for 0-1½ months only. Potash nutrition for 1½-3 months (T_8), 1½-4½ months (T_9) and zero potash are not significantly different from each other but are in the descending order respectively.

Table 26. Sand culture experiment - Swelling volume of starch (in ml)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	38.3	39.7	40.3	41.3	41.0	40.7	40.2	39.3	39.0	39.9
V_2	42.8	44.3	45.8	45.3	45.2	45.0	45.2	44.2	44.0	44.7
Mean	40.6	42.0	43.1	43.4	43.1	42.8	42.7	41.8	41.5	

C.D. at 5% for V = 0.180
" T = 0.382
" V x T = 0.541

Table 27 presents data on the reducing value of starch under different durations of potash nutrition in the sand culture experiment. The treatments receiving potash nutrition for 0-4½ months (T_4) records maximum reducing value but it is not significantly different from 0-3 months potash nutrition (T_3). Again treatment T_3 is on par with potassium application for 0-10 months (T_5) and 4½-10 months (T_6) but in a descending order.

Table 27. Sand culture experiment - Reducing value

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	0.97	1.17	1.30	1.36	1.33	1.27	1.23	1.20	1.27	1.23
V_2	1.33	1.47	1.60	1.66	1.57	1.57	1.47	1.43	1.40	1.50
Mean	1.15	1.32	1.45	1.52	1.45	1.42	1.35	1.32	1.33	

C.D. at 5% for V = 0.028
" T = 0.060
" V x T = 0.084

Here again treatment T_6 is not significantly different from 3-4½ months of potash nutrition (T_7) and are in a decreasing order. Eventhough potash nutrition for 3-4½ months (T_7), 0-1½ months (T_2), 1½-3 months (T_8) and 1½-4½ months (T_9) are in the descending order they are not significantly different from each other. The treatment which received zero potash (T_1) records the lowest reducing value and is significantly lower than all other treatments.

Table 28 presents data on the variation of hydrocyanic acid content under different durations of potash nutrition in the sand culture experiment. The HCN content is maximum in treatment receiving zero potash which is significantly different from other treatments, followed by potash nutrition for 0-1½ months (T_2). Treatments receiving potassium nutrition for 4½-10 months (T_6) and 0-3 months (T_3) are not significantly different from each other but are in the descending order.

Table 28. Sand culture experiment - Hydrocyanic acid (in $\mu g/g$)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Mean
V_1	143	132	94	42	52	80	55	51	70	80
V_2	106	104	49	40	48	70	44	49	52	61
Mean	125	118	72	41	50	75	50	50	61	

C.D. at 5% for V = 1.817
,, T = 3.854
,, V x T = 5.451

The next treatment in decreasing order is T_9 which received potash for 1½-4½ months. Treatments receiving potash nutrition for 1½-3 months (T_8), 3-4½ months (T_7) and 0-10 months (T_5) are at par as far as HCN content is concerned, but are in the descending order. The treatment which received potash nutrition for 0-4½ months (T_4) records minimum HCN and it is significantly lower than all other treatments.

FIELD (MICROPLOT) EXPERIMENT

Table 29 presents data on the yield of tubers per plant under various levels of potash nutrition in the field experiment.

Table 29. Field experiment - Yield of tubers per plant (in kg)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	1.74	2.32	3.01	2.67	2.57	2.46
V_2	1.16	1.59	2.02	1.91	1.90	1.71
Mean	1.45	1.95	2.51	2.29	2.23	

C.D. at 5% for V = 0.124
" T = 0.197
" V x T = 0.278

From the table it can be seen that potassium @ 100 kg K_2O/ha (T_3) records maximum yield which is significantly superior to all other treatments, followed by K_2O @ 150 kg/ha (T_4) and K_2O @ 200 kg/ha (T_5) which are not significantly different from each other. Potash application @ 50 kg K_2O/ha comes next in the descending order. Zero potash (T_1) records minimum yield which is significantly inferior to all other treatments.

Among the varieties, V_1 (H-2304) is significantly superior to V_2 (M-4).

Table 30 presents data on the number of tubers per plant under various levels of potash nutrition in the field experiment. Though potassium application @ 100 kg K_2O/ha (T_3)

records maximum number of tubers, it is not significantly different from potash application @ 200 kg K_2O/ha (T_5) and 150 kg K_2O/ha (T_4) which are in the descending order respectively.

Table 30. Field experiment - Number of tubers per plant (Mean)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	9.0	11.0	15.0	14.7	14.6	12.9
V_2	8.0	11.0	14.0	13.7	14.3	12.2
Mean	8.5	11.0	14.5	14.2	14.5	

C.D. at 5% for V = 0.681
,, T = 1.077
,, V x T = 1.524

Potassium @ 50 kg K_2O/ha (T_2) comes next in the descending order. Zero potash (T_1) records minimum number of tubers which is significantly inferior to all other treatments.

Variety V_1 (H-2304) and V_2 (H-4) are not significantly different.

Table 31 presents data on the mean length of tubers per plant under various levels of potash application in the field experiment. It can be seen that potash application @ 150 kg K_2O/ha (T_4) is significantly superior to all other treatments and potash application @ 200 kg K_2O/ha (T_5) comes next in descending order. Levels of potash @ 100 kg K_2O/ha (T_3) and 50 kg K_2O/ha (T_2) are the next treatments in descending order. The lowest mean length is recorded by zero potash (T_1) and it is significantly lower than all other treatments.

Table 31. Field experiment - Mean length of tubers/plant (in cm)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	26.0	29.5	36.5	38.0	37.6	33.5
V_2	21.4	28.2	35.5	35.8	34.4	30.7
Mean	23.7	28.9	36.0	36.9	36.0	

C.D. at 5% for V = 0.508
" T = 0.804
" V x T = 1.136

Variety V_1 (H-2304) is significantly superior to V_2 (H-4). The V x T interaction is also significant.

Table 32 presents data on the mean girth of tubers per plant under various levels of potash in the field experiment.

Table 32. Field experiment - Mean girth of tubers/plant (in cm)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	21.3	21.5	22.7	22.8	23.1	22.2
V_2	18.3	20.2	22.9	22.1	22.9	21.3
Mean	19.8	20.8	22.8	22.5	23.0	

C.D. at 5% for V = 0.439
" T = 0.662
" V x T = 0.936

Though K_2O @ 200 kg/ha (T_5) records maximum girth of tubers, it is not significantly different from potash @ 150 kg K_2O/ha

(T_4), 100 kg K_2O/ha (T_3) and 50 kg K_2O/ha (T_2) but in the descending order. The treatment receiving zero potash (T_1) records minimum girth of tubers and this is significantly lower than all other treatments.

Variety V_1 (H-2304) is significantly superior to V_2 (H-4) as far as girth of tuber is concerned and V x T interaction is also significant.

Table 33 presents data on the mean height of plants due to various levels of potash application in the field experiment. The treatment receiving potash @ 200 kg K_2O/ha (T_5) records maximum height, but it is at par with potash @ 150 kg K_2O/ha (T_4) which is the second in descending order.

Table 33. Field experiment - Mean height of plants (in cm)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	166.1	175.1	186.4	188.2	191.9	181.6
V_2	175.2	190.3	199.9	208.2	213.8	197.5
Mean	170.7	182.7	193.2	198.2	202.9	

C.D. at 5% for V = 2.920
,, T = 4.618
,, V x T = 6.530

The next treatments in the descending order are those which received potash @ 100 kg K_2O/ha (T_3), @ 50 kg K_2O/ha (T_2) and zero potash (T_1) and are significantly different from each other. Zero potash (T_1) records minimum height.

Mean height of variety V_2 (H-4) is significantly higher than variety V_1 (H-2304).

Table 34 presents data on the girth of stem under various levels of potash nutrition in the field experiment. Though the level of potash @ 200 kg K_2O/ha (T_5) records maximum girth of stem it is not significantly different from potash level @ 150 kg K_2O/ha. The next level in the descending order is potassium @ 100 kg K_2O/ha (T_3) followed by potash level @ 50 kg K_2O/ha (T_2).

Table 34. Field experiment - Mean girth of stem (in cm)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	6.1	7.2	8.1	8.9	8.9	7.8
V_2	6.1	6.8	7.8	8.8	9.3	7.8
Mean	6.1	7.0	8.0	8.9	9.1	

C.D. at 5% for V = 0.296
,, T = 0.467

Zero potash (T_1) records minimum girth of stem which is significantly lower than all other treatments.

Between the varieties there is no significant difference in the girth of stem.

Table 35 presents data on the length of petiole under various levels of potash nutrition in the field experiment. Eventhough potash @ 200 kg K_2O/ha (T_5) records maximum length of petiole it is not significantly different from potash @ 150 kg K_2O/ha (T_4). The treatments receiving potash @ 100 kg K_2O/ha (T_3) and @ 50 kg K_2O/ha (T_2) record still lower lengths of petiole, but in the descending order. The minimum length of petiole is recorded by zero potash (T_1) and it is significantly lower than all other treatments.

Table 35. Field experiment - Mean length of petiole (in cm)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	14.8	19.0	25.4	26.9	29.0	23.5
V_2	14.8	20.5	27.7	29.7	29.9	23.0
Mean	14.8	19.8	26.6	28.3	29.5	

C.D. at 5% for V = 0.896

,, T = 1.417

Variety V_1 (H-2304) is significantly superior to variety V_2 (M-4) as far as length of petiole is concerned.

Table 36 presents data on the variation in total number of leaves under different levels of potassium in the field experiment. Level of potassium @ 100 kg K_2O/ha records maximum number of leaves which is not significantly different from potash @ 150 kg K_2O/ha and is in the descending order. The next treatments in descending order are potassium @ 200 kg K_2O/ha and 50 kg K_2O/ha respectively which are not significantly different from each other. The lowest number of leaves is recorded by zero potassium (T_1).

The varieties are not significantly different as far as number of leaves is concerned.

Table 37 presents data on the number of leaves retained (expressed as per cent of total number of leaves) under different levels of potassium in the field experiment.

Table 36. Field experiment - Total number of leaves

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	195.3	201.3	221.0	222.0	201.0	207.7
V_2	197.0	193.3	214.0	204.3	207.0	203.1
Mean	195.2	197.2	217.5	213.2	204.0	

C.D. at 5% for T = 9.978

Table 37. Field experiment - Number of leaves retained (%)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	31.1	40.3	48.2	48.0	50.7	43.7
V_2	32.8	41.6	46.3	50.0	50.4	44.2
Mean	32.0	41.0	47.3	49.0	50.6	

C.D. at 5% for T = 7.194

As the level of potassium increases the per cent of leaves retained also increases the maximum being in potassium level @ 200 kg K_2O/ha (T_5) and minimum in zero potassium treatment (T_1). The other treatments come intermediate between these two treatments and are proportional to the level of potassium. There is no significant difference between the two varieties.

Table 38 presents data on the number of leaves shed (expressed as per cent of total number of leaves) under different levels of potassium. The minimum per cent of leaves shed is in potassium application @ 200 kg K_2O/ha (T_5) and the maximum in zero potassium (T_1). Eventhough potassium @ 100 kg K_2O/ha (T_3) records a little more per cent of leaves shed than potassium @ 150 kg K_2O/ha (T_4), they are not significantly different.

Table 38. Field experiment - Number of leaves shed (%)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	69.9	59.7	51.8	52.0	49.3	56.5
V_2	67.2	58.4	53.7	50.0	49.6	55.8
Mean	68.1	59.1	52.8	51.0	49.5	

C.D. at 5% for T = 6.091

Table 39 presents data on the dry matter content of flesh under different levels of potassium in the field experiment.

Table 39. Field experiment - Dry matter content of flesh (%)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	36.84	38.03	44.68	38.73	39.57	39.97
V_2	36.37	37.67	41.46	39.75	40.51	39.11
Mean	36.60	37.85	43.07	39.14	40.04	

C.D. at 5% for T = 1.764

The level of potash @ 100 kg K_2O/ha (T_3) records maximum dry matter content of flesh which is significantly superior to all other treatments. Potassium @ 150 kg K_2O/ha (T_4) and 200 kg K_2O/ha (T_5) records still lower dry matter contents of flesh in the descending order and are not significantly different from each tother. Zero level of potash (T_1) records minimum per cent of dry matter in the flesh which is not significantly different from potash @ 50 kg K_2O/ha (T_2).

There is no significant difference between the varieties as far as dry matter of flesh content is concerned.

Table 40 presents data on the dry matter per cent of rind under different levels of potash in the field experiment.

Table 40. Field experiment - Dry matter content of rind (%)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	16.43	18.94	22.73	20.76	21.94	20.16
V_2	15.24	16.72	20.92	19.81	18.67	18.27
Mean	15.94	17.83	19.72	20.88	21.65	

C.D. at 5% for V = 0.074
,, T = 0.110
,, V x T = 0.157

Potash level @ 100 kg K_2O/ha (T_3) records maximum dry matter content of rind which is significantly superior to all other levels followed by potash @ 150 kg K_2O/ha (T_4) and 200 kg K_2O/ha (T_5) in the descending order. Potassium @ 50 kg K_2O/ha (T_2) comes next in the decreasing order. Zero potash (T_1) records minimum dry matter per cent of rind. All treatments are significantly different from each other.

Among the varieties studied H-2304 (V_1) is having significantly more dry matter content of rind when compared to H-4 (V_2). The V x T interaction is also significant.

Table 41 presents data on the rind content of tubers under different levels of potash in the field experiment.

Table 41. Field experiment - Rind content of tubers (%)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	14.57	14.36	13.61	13.56	14.72	14.16
V_2	14.70	13.67	13.42	13.30	11.45	13.31
Mean	14.64	14.01	13.52	13.43	13.09	

N.S.

Eventhough the level of potash @ 200 kg K_2O/ha (T_5) records minimum rind content it is not significantly different from other treatments. Potash @ 150 kg K_2O/ha (T_4), 100 kg K_2O/ha (T_3), 50 kg K_2O/ha (T_2) come next in the ascending order. Maximum rind content is recorded by zero potash (T_1). Eventhough there is no significant difference between the treatments the rind content is generally decreasing as the level of potash increases.

Table 42 shows data on the fibre content of tubers under different levels of potash in the field experiment. Zero potash treatment (T_1) records maximum fibre content which is significantly higher than all other levels. The levels which follow in the descending order are: Potash @ 50 kg K_2O/ha (T_2), @ 100 kg K_2O/ha (T_3), @ 150 kg K_2O/ha (T_4) and @ 200 kg K_2O/ha (T_5), which are significantly different from each other. Generally fibre content decreases as the levels of potassium increase.

Table 42. Field experiment - Crude fibre content of tubers (%)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	1.94	1.90	1.87	1.86	1.81	1.88
V_2	1.73	1.74	1.70	1.68	1.65	1.70
Mean	1.83	1.82	1.79	1.77	1.73	

C.D. at 5% for V = 0.015
" T = 0.021

Variety H-2304 (V_1) is having significantly more fibre content when compared to variety M-4 (V_2).

Table 43 presents data on the variation of starch content in tubers under different levels of potash in the field experiment.

Table 43. Field experiment - Starch content of tubers (% on fresh weight basis)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	27.54	29.74	30.07	29.93	30.00	29.46
V_2	26.36	27.73	29.81	29.56	29.68	28.63
Mean	26.95	28.74	29.94	29.74	29.84	

C.D. at 5% for V = 0.196
" T = 0.311
" V x T = 0.439

The level of potash @ 100 kg K_2O/ha (T_3) records maximum starch content, but it is not significantly different from potash level @ 200 kg K_2O/ha (T_5) and 150 kg K_2O/ha (T_4) which follow in a descending order. The next two levels in decreasing order are potash @ 50 kg K_2O/ha (T_2) and zero potash (T_1) which are significantly different from each other. Zero potash (T_1) records minimum starch content.

Variety H-2304 (V_1) is significantly superior to variety H-4 (V_2) as far as starch content of tubers is concerned. The V x T interaction is also significant.

Table 44 presents data on the reducing sugar content of tubers under different levels of potash in the field experiment.

Table 44. Field experiment - Reducing sugar content of tubers (% on fresh weight basis)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	1.72	1.84	1.89	1.91	1.90	1.84
V_2	1.64	1.75	1.95	1.93	1.94	1.85
Mean	1.68	1.80	1.92	1.92	1.92	

C.D. at 5% for T = 0.019

,, V x T = 0.027

Eventhough the level of potash @ 100 kg K_2O/ha (T_3) records maximum reducing sugar it is not significantly different from potash @ 150 kg K_2O/ha (T_4) and 200 kg K_2O/ha (T_5) which are in a descending order. The next level in decreasing order is potassium @ 50 kg K_2O/ha (T_2). Zero potash (T_1) records minimum reducing sugar content and this is significantly lower than all other treatments.

Variety H-2304 (V_1) is significantly superior to variety H-4 (V_2) as far as starch content of tubers is concerned. The V x T interaction is also significant.

Table 45 presents data on the variation of amylose content of starch in tubers at different levels of potassium in the field experiment. Eventhough potash @ 200 kg K_2O/ha (T_5) records maximum amylose content it is not significantly different from potash @ 150 kg K_2O/ha (T_4) and 100 kg K_2O/ha (T_3) which are themselves in a descending order. Though potash @ 50 kg K_2O/ha records minimum amylose content it is not significantly different from zero potash (T_1) and potash @ 100 kg K_2O/ha which are in an ascending order.

Table 45. Field experiment - Amylose content of starch (%)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	20.73	14.92	22.11	21.83	21.86	20.29
V_2	28.30	29.66	29.97	29.93	29.92	29.56
Mean	24.52	22.29	26.04	25.[illegible]	25.89	

C.D. at 5% for V = 2.854

Variety M-4 (V_2) is significantly superior to variety H-2304 (V_1) as far as amylose content is concerned.

Table 46 presents data on the granule size of starch in tubers under different levels of potash in the field experiment. It can be seen that potash @ 200 kg K_2O/ha (T_5) records maximum granule size eventhough it is not significantly different from potash @ 150 kg K_2O/ha (T_4) and 100 kg K_2O/ha (T_3) which are in a descending order. The next level in the decreasing order is potash @ 50 kg K_2O/ha (T_2). Zero potash

(T_1) records minimum granule size and this is significantly lower than all other treatments.

Table 46. Field experiment - Granule size of starch (in μ)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	10.83	16.17	27.57	27.73	27.93	22.05
V_2	11.47	19.63	28.70	29.93	29.90	23.93
Mean	11.15	17.90	28.13	28.83	28.92	

C.D. at 5% for V = 0.695

" T = 1.098

Among the varieties, H-4 (V_2) is having significantly higher granule size than H-2304 (V_1).

Table 47 shows data on the variation in the alkali numbers of starch under different levels of potash in the field experiment. From the data it can be seen that there is no significant difference between the levels as far as alkali numbers are concerned. Eventhough potash @ 50 kg K_2O/ha (T_2) records maximum alkali number it is not significantly different from potash @ 150 kg K_2O/ha (T_4), 200 kg K_2O/ha (T_5), 100 kg K_2O/ha (T_3) and zero potash (T_1) which are in the descending order.

Variety H-4 (V_2) is having significantly higher reducing value than variety H-2304 (V_1). The V x T interaction is significant.

Table 47. Field experiment - Alkali number (in ml of 0.1 N NaOH)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	7.7	8.0	7.5	8.0	7.7	7.8
V_2	8.1	8.7	8.4	8.4	8.6	8.6
Mean	7.9	8.4	7.9	8.2	8.3	

C.D. at 5% for V = 0.203

" V x T = 0.453

Table 48 presents data on the variation in pasting temperatures of starch under different levels of potash in the field experiment. Potash @ 200 kg K_2O/ha (T_5) records maximum pasting temperature and this is significantly higher than all other treatments. The next two treatments in descending order are potash @ 150 kg K_2O/ha (T_4) and 100 kg K_2O/ha (T_3) which are not significantly different from each other.

Table 48. Field experiment - Pasting temperature (in °C)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	59.0	61.2	64.5	65.9	68.5	63.7
V_2	66.2	65.5	67.8	67.5	69.7	67.5
Mean	62.6	63.8	66.2	66.5	69.1	

C.D. at 5% for V = 0.445

" T = 0.703

" V x T = 0.959

The level of potash @ 50 kg K_2O/ha (T_2) comes next in decreasing order. Zero potash (T_1) records minimum pasting temperature which is significantly lower than all other treatments.

Variety M-4 (V_2) is having significantly higher pasting temperature than variety H-2304 (V_1). The V x T interaction is also significant.

Table 49 presents data on the variation in viscosity of starch under different levels of potash in the field experiment.

Table 49. Field experiment - Viscosity of 2% starch paste (in seconds)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	54.8	54.8	55.8	56.5	56.8	55.8
V_2	55.7	56.3	57.5	57.7	58.2	57.1
Mean	55.3	55.6	56.7	57.1	57.5	

C.D. at 5% for V = 0.327

" T = 0.517

" V x T = 0.731

Eventhough potash @ 200 kg K_2O/ha (T_5) records maximum viscosity of starch, it is not significantly different from potash @ 150 kg K_2O/ha (T_4). Again potash @ 150 kg K_2O/ha (T_4) and 100 kg K_2O/ha (T_3) have similar effects, but are in the descending order. The next level in decreasing order is potash @ 50 kg K_2O/ha (T_2) which is not significantly different from zero potash (T_1) recording the minimum viscosity.

Variety M-4 (V_2) is having significantly higher viscosity than variety H-2304 (V_1). The V x T interaction is also significant.

Table 50 presents data on the variation in swelling volume of starch under different levels of potash in the field experiment. The maximum swelling volume is recorded by potash @ 200 kg K_2O/ha (T_5), but it is not significantly different from potash @ 150 kg K_2O/ha (T_4). The next two treatments in the descending order are potash @ 100 kg K_2O/ha (T_3) and 50 kg K_2O/ha (T_2) respectively, which are not significantly different from each other. Zero potash (T_1) records minimum swelling volume which is significantly lower than all other treatments.

Table 50. Field experiment - Swelling volume of starch (in ml)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	37.5	38.8	39.5	41.3	42.3	39.9
V_2	44.2	45.2	46.0	47.5	47.2	46.0
Mean	40.8	42.0	42.8	44.4	44.8	

C.D. at 5% for V = 0.731
,, T = 1.156

Variety M-4 (V_2) records significantly higher swelling volume of starch than variety H-2304 (V_1).

Table 51 shows data on the reducing value of starch under different levels of potash in the field experiment. Eventhough potash @ 150 kg K_2O/ha (T_4) records maximum reducing value, it is not significantly different from potash application @ 100 kg K_2O/ha (T_3). The next level in descending order is potash @ 200 kg K_2O/ha (T_5) followed by zero potash.

The minimum reducing value is recorded by potash @ 50 kg K_2O/ha (T_2) which is not significantly different from zero potash.

Table 51. Field experiment - Reducing value of starch

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	1.30	1.30	1.30	1.30	1.27	1.29
V_2	1.50	1.47	1.63	1.70	1.45	1.54
Mean	1.40	1.38	1.47	1.50	1.35	

C.D. at 5% for V = 0.063

" T = 0.099

Among the varieties M-4 (V_2) records significantly higher reducing value than H-2304 (V_1).

Table 52, presents the variation of hydrocyanic acid in the tubers under different levels of potash in the field experiment. Zero potash (T_1) records maximum HCN content which is significantly higher than all other treatments followed by potash @ 50 kg K_2O/ha (T_2) and 100 kg K_2O/ha in the descending order. The next level in the decreasing order is potash @ 150 kg K_2O/ha, which is not significantly different from potash @ 200 kg K_2O/ha. Generally the HCN content decreases as the levels of potash increase.

Table 52. Field experiment - Hydrocyanic acid in tubers (µg/g)

	T_1	T_2	T_3	T_4	T_5	Mean
V_1	119.0	79.0	50.0	49.0	50.0	69.6
V_2	104.0	64.0	49.0	40.0	38.0	59.0
Mean	111.5	71.5	49.5	44.5	44.0	

C.D. at 5% for V = 3.348
,, T = 5.293

Variety H-2304 (V_1) is having significantly higher HCN content than variety M-4 (V_2).

Path analysis for yield and yield components and starch and starch characters

1. Sand culture experiment

(a) Yield and yield components

For variety N-2304, maximum direct effect is for number of leaves retained (C_9). Its correlation with yield is high and significant ($r=0.755$). This correlation is due to the direct effect of the number of leaves retained (C_9) via number of tubers per plant (C_2) and length of tuber (C_3). Number of leaves retained (C_9) influences indirectly on yield (C_1) through the other factors like number of tubers per plant (C_2), length of tuber (C_3), girth of tuber (C_4), height of plant (C_5), girth of stem (C_6), length of petiole (C_7), dry matter of flesh (C_{10}) and dry matter of rind (C_{11}). The correlation of yield (C_1) with the above factors is significant (refer path diagram 3) and table 95), which is mainly not due to their direct effects on yield (C_1) but through indirect effect via number of leaves retained (C_9) and length of tubers (C_3). Total number of tubers per plant is another factor which contributes directly or indirectly to the yield (C_1).

For variety N-4, girth of stem (C_6) and dry matter content of rind (C_{11}) are the most important factors which contribute directly to the yield (C_1). The direct effects of all other factors are either negligible or negative (refer path diagram 4 and table 96). But the significant positive correlation of other factors with the yield (C_1) is mainly due to the indirect effect via girth of stem (C_6) and dry matter content of rind (C_{11}).

(b) Starch and starch characters

As the HCN content (C_{10}) increased the starch content (C_1) decreases in variety H-2304 (refer path diagram 7 and table 59). Maximum direct effect (r=0.514) is due to amylose content (C_3) on starch (C_1), while the indirect effects of other factors are negligible, followed by swelling volume (C_8). The correlation of all factors with starch content (C_1) is highly significant (refer table 59). This is mainly due to either the direct effect or due to indirect effect via amylose content (C_3).

For variety H-4, the correlation of HCN content (C_{10}) with starch content (C_1) is negative and significant (r= -0.646). Maximum direct effect is via reducing sugar (C_2) followed by viscosity (C_7). The correlation of all factors with starch content (C_1) is significant (refer path diagram 8 and table 60). This significant correlation is due to the direct and indirect effect of amylose content (C_2).

II. Field experiment

(a) Yield and yield components.

The correlations between the yield (C_1) and the other factors (except number of leaves fallen in C_8 and fibre content of tuber i.e. C_{13} are significant (refer path diagram 1 and table 53). The maximum direct effect is via dry matter content rind (r=2.021) i.e. C_{11}. The high positive correlation of dry matter content of rind (C_{11}) is mainly due to the positive direct effect of the same and positive indirect effect via length of tuber (C_3) and height of plant (C_5). Length of tuber (C_3) and height of plant (C_5) are the main controlling factors of dry matter content of rind (C_{11}) in contributing for the yield (C_1). Height of plant (C_5) is another important factor affecting the yield (C_1). Its direct effect on yield (C_1) and its correlation with the yield are almost equal in magnitude (r=0.722 and 0.001 respectively) indicating that height of plant (C_5) is the most important factor influencing the yield. The significant correlation of yield (C_1) with number of tubers per plant (C_2), girth of tuber (C_4), girth of stem (C_6), length of petiole (C_7) and number of leaves retained (C_9) is due to the positive indirect effect via length of tuber (C_3). The direct effect of length of tuber (C_3) is also significant and high (r=1.960).

(b) Starch and starch characters

In variety H-2304, correlation of starch content (C_1)

with all factors except reducing value (C_9) is highly significant (refer path diagram 5 and table 57). The positive direct effect on starch content (C_1) is through amylose content (C_3) and maximum negative direct effect (r=1-393) is via HCN content (C_{10}) while the direct effect of other factors are negligible. From the path analysis it can be observed that the correlation between HCN content (C_{10}) and starch content (C_1) is negative which means that as the HCN content increases the starch content decreases. This large negative correlation (r=-0.913) is mainly due to the negative direct effect of HCN content (C_{10}). Amylose content (C_3) is a factor which also contribute indirectly to starch content (C_1).

From the path analysis for variety H-4, it can be observed that HCN content (C_{10}) increases as the starch content (C_1) decreases (refer path diagram 6 and table 60), which is on par with the result of variety H-2304. The correlation between all factors except alkali number (C_5) and number of leaves retained (C_9) is significant (refer table 60). The maximum contributing factor to the starch content (C_1) either directly or indirectly is reducing sugar (C_2) followed by amylose content (C_3). The direct effect of all other factors are negligible.

Table 53. Field experiment - Yield attributes (Y_1)

	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	Total corre-lation
C_2	-1.292	1.843	0.237	0.693	-0.517	-1.594	0.371	0.311	-0.008	1.830	-1.106	-0.030	0.818**
C_3	-1.185	1.968	0.269	0.693	-0.557	-1.677	0.388	0.300	-0.008	1.944	-1.262	-0.032	0.841**
C_4	-0.942	1.663	0.318	0.575	-0.490	-1.378	0.300	0.184	-0.008	1.589	-1.105	-0.031	0.676**
C_5	-1.214	1.807	0.253	0.722	-0.550	-1.637	0.378	0.314	-0.009	1.926	-1.238	-0.032	0.801**
C_6	-1.103	1.850	0.263	0.671	-0.592	-1.586	0.383	0.279	-0.010	1.944	-1.419	-0.035	0.645*
C_7	-1.190	1.947	0.259	0.698	-0.555	-1.694	0.385	0.322	-0.008	1.981	-1.258	-0.031	0.857**
C_8	1.156	-1.078	-0.235	-0.673	0.558	1.607	-0.406	-0.300	0.008	-1.934	1.329	0.032	0.755**
C_9	-1.083	1.625	0.161	0.624	-0.457	-1.504	0.336	0.363	-0.006	1.781	-1.009	-0.021	0.810**
C_{10}	-0.694	1.170	0.190	0.468	-0.420	-1.037	0.246	0.161	-0.014	1.391	-1.104	-0.031	0.356(NS)
C_{11}	-1.178	1.894	0.250	0.680	-0.510	-1.661	0.309	0.320	-0.010	2.021	-1.359	-0.032	0.773**
C_{12}	0.944	-1.675	-0.257	-0.605	0.507	1.438	-0.364	-0.247	0.010	-1.825	1.482	0.035	-0.478(NS)
C_{13}	0.997	-1.660	-0.261	-0.614	0.542	1.376	-0.339	-0.204	0.113	-1.718	1.315	0.038	-0.510*

Residual 0.028787 (R^2 = 0.000829)

Table 54. Field experiment - Yield attributes (Y_2)

	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	Total Correlation
c_2	-0.179	0.500	-0.023	-1.125	0.109	0.366	0.679	0.517	1.223	-1.172	-0.181	0.001	0.837
c_3	-0.164	0.637	-0.032	-1.240	0.120	0.396	0.741	0.539	1.275	-1.253	-0.186	0.001	0.847
c_4	-0.158	0.620	-0.034	-1.175	0.111	0.367	0.730	0.546	1.230	-1.214	-0.185	0.001	0.861
c_5	-0.150	0.600	-0.030	-1.348	0.121	0.399	0.758	0.488	1.299	-1.280	-0.182	0.001	0.687
c_6	-0.151	0.606	-0.029	-1.262	0.132	0.393	0.723	0.467	1.261	-1.235	-0.179	0.001	0.726
c_7	-0.156	0.616	-0.031	-1.275	0.121	0.422	0.784	0.403	1.314	-1.293	-0.194	0.002	0.792
c_8	0.142	-0.576	0.029	1.191	-0.109	-0.326	-0.859	-0.427	-1.321	1.302	0.192	-0.002	-0.815
c_9	-0.140	0.564	-0.030	-1.051	0.097	0.328	0.584	0.627	1.004	-1.000	-0.147	0.001	0.830
c_{10}	-0.150	0.609	-0.030	-1.273	0.119	0.403	0.825	0.458	1.376	-1.340	-0.196	0.002	0.791
c_{11}	-0.156	0.611	-0.031	-1.281	0.118	0.407	0.830	0.466	1.369	-1.346	-0.197	0.002	0.792
c_{12}	0.159	-0.598	0.031	1.203	-0.114	-0.400	-0.807	-0.451	-1.321	1.295	0.204	-0.002	-0.798
c_{13}	0.149	-0.557	0.028	1.160	-0.106	-0.374	-0.824	-0.419	-1.320	1.290	0.185	-0.002	-0.770

Residual 0.181735 (R^2 = 0.033028)

Table 55. Sand culture experiment – Yield attributes (Y_1)

	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	Total corre-lation
C_2	0.255	0.281	0.070	0.045	-0.228	0.169	0.004	0.621	-0.122	-0.037	-0.283	0.117	0.914
C_3	0.206	0.343	0.077	0.047	-0.281	0.202	0.002	0.552	-0.121	-0.037	-0.231	0.091	0.855
C_4	0.169	0.252	0.105	0.051	-0.309	0.203	-0.005	0.513	-0.080	-0.034	-0.167	0.048	0.748
C_5	0.161	0.229	0.074	0.073	-0.338	0.204	-0.002	0.559	-0.106	-0.026	-0.243	0.088	0.670
C_6	0.149	0.250	0.003	0.063	-0.391	0.206	-0.004	0.533	-0.090	-0.291	-0.187	0.062	0.614
C_7	0.201	0.293	0.090	0.062	-0.327	0.240	-0.003	0.533	-0.127	-0.041	-0.256	0.101	0.765
C_8	-0.046	-0.004	0.026	0.007	-0.060	0.031	-0.023	-0.232	0.034	0.007	0.126	-0.058	-0.191
C_9	0.210	0.255	0.721	0.0541	-0.277	0.170	0.007	0.753	-0.108	-0.035	-0.268	0.091	0.924
C_{10}	0.204	0.277	0.056	0.051	-0.231	0.200	0.005	0.535	-0.152	-0.042	-0.300	0.132	0.734
C_{11}	0.145	0.209	0.055	0.030	-0.178	0.152	0.003	0.417	-0.100	-0.064	-0.166	0.086	0.563
C_{12}	-0.215	-0.240	-0.053	-0.053	0.217	-0.183	-0.009	-0.605	0.136	0.035	0.336	-0.146	-0.777
C_{13}	-0.181	-0.193	-0.031	-0.039	0.148	-0.147	-0.008	-0.418	0.122	0.034	0.298	-0.164	-0.579

Residual 0.106591 (R^2 = 0.011362)

Table 56. Sand culture experiment - Yield attributes (Y_2)

	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	Total correlation
c_2	0.107	-0.005	-0.069	-0.246	0.414	-0.001	0.028	0.002	-0.190	0.690	-0.101	-0.002	0.596
c_3	0.079	-0.007	-0.105	-0.020	0.772	-0.248	0.078	0.013	-0.176	0.769	-0.121	-0.007	0.842
c_4	0.065	-0.006	-0.114	-0.171	0.828	-0.330	0.071	0.003	-0.153	0.760	-0.120	-0.005	0.856
c_5	0.062	-0.003	-0.046	-0.427	0.196	0.127	0.035	0.011	-0.156	0.522	-0.050	-0.006	0.266
c_6	0.049	-0.006	-0.103	-0.091	0.922	-0.437	0.077	0.005	-0.130	0.666	-0.393	-0.009	0.848
c_7	0.001	-0.003	-0.001	0.102	0.759	-0.552	0.042	0.002	-0.035	0.375	-0.044	-0.003	0.594
c_8	0.015	-0.003	-0.040	-0.077	0.352	-0.111	0.225	-0.004	-0.085	0.001	-0.047	-0.010	0.276
c_9	0.009	-0.004	-0.318	-0.227	0.213	-0.042	-0.038	0.021	-0.044	0.228	0.048	-0.019	0.137
c_{10}	0.081	-0.006	-0.085	-0.318	0.573	-0.099	0.081	0.004	-0.210	0.771	-0.112	-0.005	0.587
c_{11}	0.075	-0.006	-0.097	-0.249	0.666	-0.222	0.018	0.005	-0.181	0.894	-0.109	-0.003	0.811
c_{12}	-0.063	0.005	0.075	0.122	-0.494	0.136	-0.055	0.006	0.136	-0.561	0.173	-0.002	-0.523
c_{13}	-0.008	0.002	0.025	0.085	-0.271	0.063	-0.068	0.007	0.037	-0.089	-0.013	0.029	-0.227

Residual 0.37894 (R^2 = 0.143595)

Table 57. Field experiment - Starch characters (Y_1)

	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Total corre-lation
C_2	0.105	0.267	-0.496	-0.061	-0.033	0.001	-0.028	0.001	0.996	0.752**
C_3	0.075	0.378	-0.607	-0.074	-0.056	0.001	-0.033	0.007	1.239	0.930**
C_4	0.071	0.311	-0.070	-0.059	-0.065	0.001	-0.042	0.005	1.335	0.801**
C_5	0.047	0.202	-0.314	-0.138	-0.006	0.001	-0.011	0.013	0.703	0.574**
C_6	0.034	0.200	-0.593	-0.008	-0.107	0.002	-0.037	0.016	0.959	0.465**
C_7	0.050	0.251	-0.579	-0.003	-0.091	0.002	-0.039	0.008	0.972	0.552**
C_8	0.052	0.221	-0.554	-0.027	-0.070	0.002	-0.056	0.002	1.020	0.598**
C_9	0.003	0.054	-0.080	-0.035	-0.035	0.001	-0.003	0.070	0.176	0.151
C_{10}	-0.076	-0.337	0.708	0.078	0.073	-0.002	0.041	0.006	-1.393	-0.915

Residual 0.202890 (R^2 = 0.041164

Table 58. Field experiment - Starch characters (V_2)

	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	Total correlation
c_2	0.858	-0.087	0.085	-0.002	-0.093	0.223	-0.127	-0.031	0.145	0.987**
c_3	0.762	-0.099	0.077	0.001	-0.064	0.198	-0.112	-0.025	0.147	0.864**
c_4	0.853	-0.090	0.085	-0.001	-0.091	0.236	-0.129	-0.030	0.150	0.985**
c_5	-0.144	-0.003	-0.007	0.011	0.037	-0.040	0.038	0.074	-0.128	-0.161
c_6	0.600	-0.047	0.057	0.003	-0.134	0.205	-0.102	0.003	0.092	0.671**
c_7	0.790	-0.078	0.079	-0.002	-0.109	0.252	-0.131	-0.025	0.135	0.915**
c_8	0.755	-0.075	0.075	-0.003	-0.094	0.226	-0.145	-0.013	0.135	0.861**
c_9	0.309	-0.029	0.030	-0.010	0.004	0.073	-0.022	-0.086	0.049	0.319
c_{10}	-0.011	0.094	-0.082	0.009	0.050	-0.221	0.127	0.027	-0.155	-0.932

Residual 0.132213 (R^2 = 0.017480)

Table 59. Sand culture experiment - Starch characters (V_1)

	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Total correlation
C_2	-0.001	0.270	0.175	0.064	-0.035	0.015	0.135	-0.145	0.278	0.755**
C_3	-0.001	0.314	0.087	0.044	-0.045	0.011	0.207	-0.132	0.065	0.751**
C_4	-0.001	0.227	0.193	0.061	-0.042	0.015	0.105	-0.125	0.273	0.709**
C_5	-0.001	0.295	0.155	0.079	-0.057	0.016	0.173	-0.146	0.298	0.806**
C_6	-0.001	0.390	0.140	0.068	-0.059	0.016	0.227	-0.137	0.219	0.864**
C_7	-0.001	0.282	0.152	0.967	-0.049	0.019	0.142	-0.127	0.240	0.734**
C_8	-0.001	0.368	0.070	0.047	-0.046	0.009	0.289	-0.110	0.125	0.754**
C_9	-0.001	0.302	0.138	0.065	-0.046	0.014	0.179	-0.178	0.234	0.787**
C_{10}	0.001	-0.095	-0.155	-0.067	0.037	-0.014	-0.104	0.119	-0.359	-0.620**

Residual 0.386639 (R^2 = 0.149490)

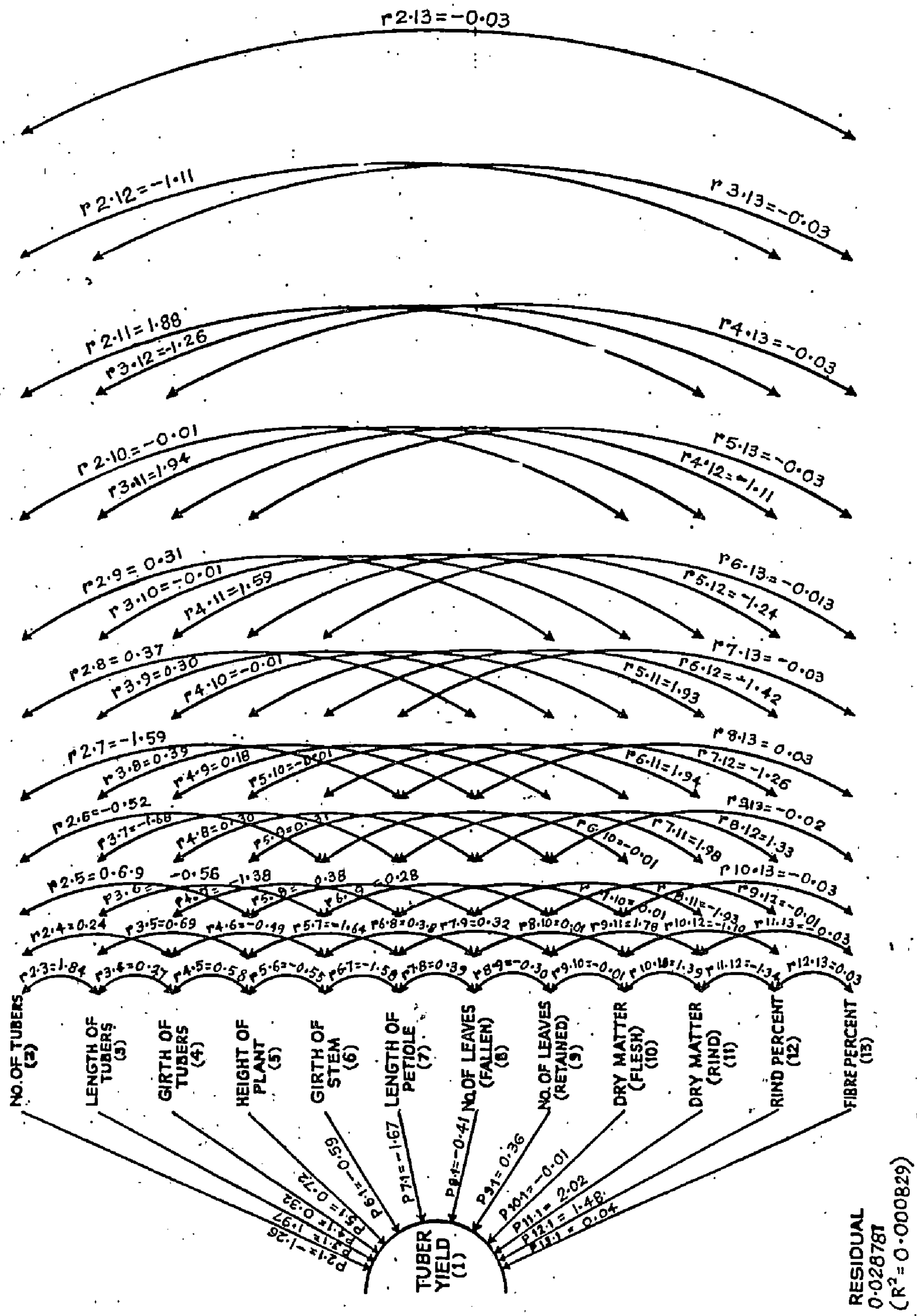
Table 60. Sand culture experiment - Starch characters (V_2)

	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Total corre-lation
C_2	1.016	-0.068	-0.385	0.035	0.077	0.124	0.075	-0.124	0.068	0.816**
C_3	0.667	-0.192	-0.325	0.046	0.112	0.214	0.141	-0.193	0.069	0.628**
C_4	0.929	-0.080	-0.418	0.041	0.091	0.168	0.090	-0.148	0.067	0.738**
C_5	0.658	-0.095	-0.341	0.050	0.105	0.198	0.122	-0.182	0.065	0.575**
C_6	0.658	-0.098	-0.322	0.044	0.118	0.225	0.158	-0.181	0.064	0.646**
C_7	0.405	-0.071	-0.225	0.032	0.085	0.311	0.121	-0.167	0.036	0.527**
C_8	0.428	-0.084	-0.218	0.035	0.094	0.217	0.173	-0.181	0.070	0.535**
C_9	0.570	-0.090	-0.202	0.042	0.097	0.257	0.142	-0.220	0.054	0.549**
C_{10}	-0.669	0.069	0.272	-0.050	-0.075	-0.109	-0.118	-0.116	-0.103	-0.646**

Residual 0.40757 (R^2 = 257822)

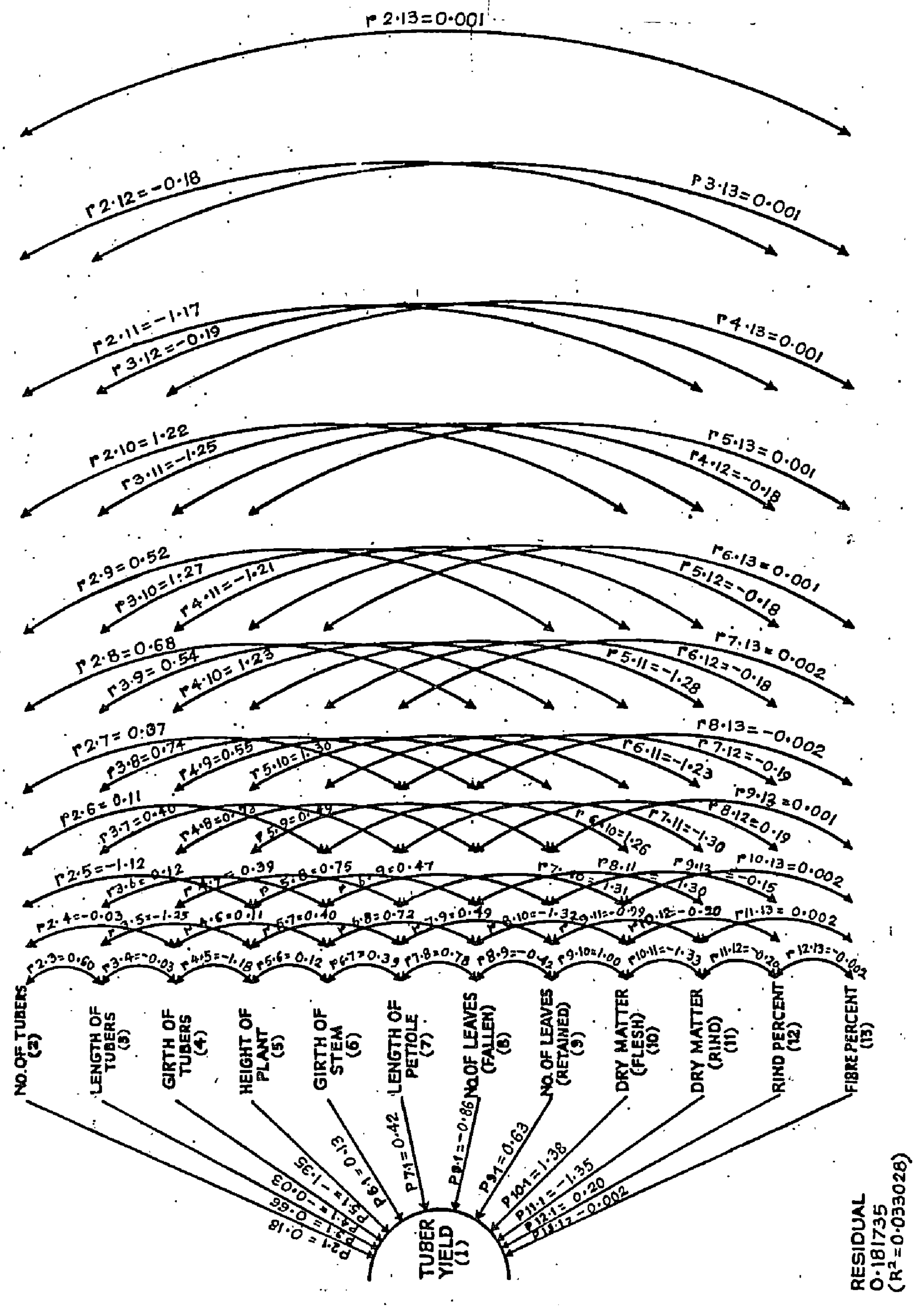
PATH DIAGRAM-1

FIELD EXPERIMENT- YIELD COMPONENTS (V_1)



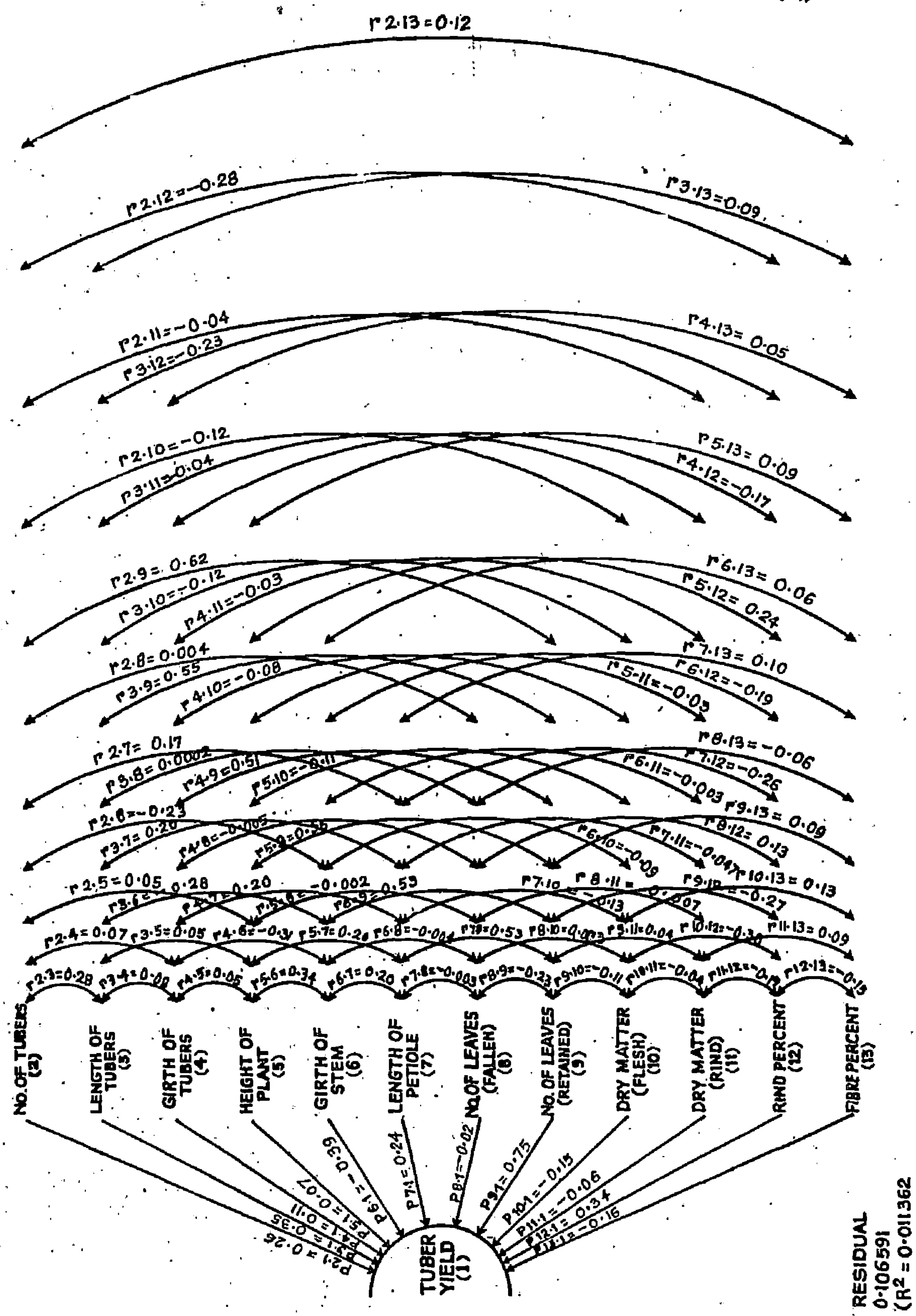
PATH DIAGRAM·2

FIELD EXPERIMENT - YIELD COMPONENTS (V_2)



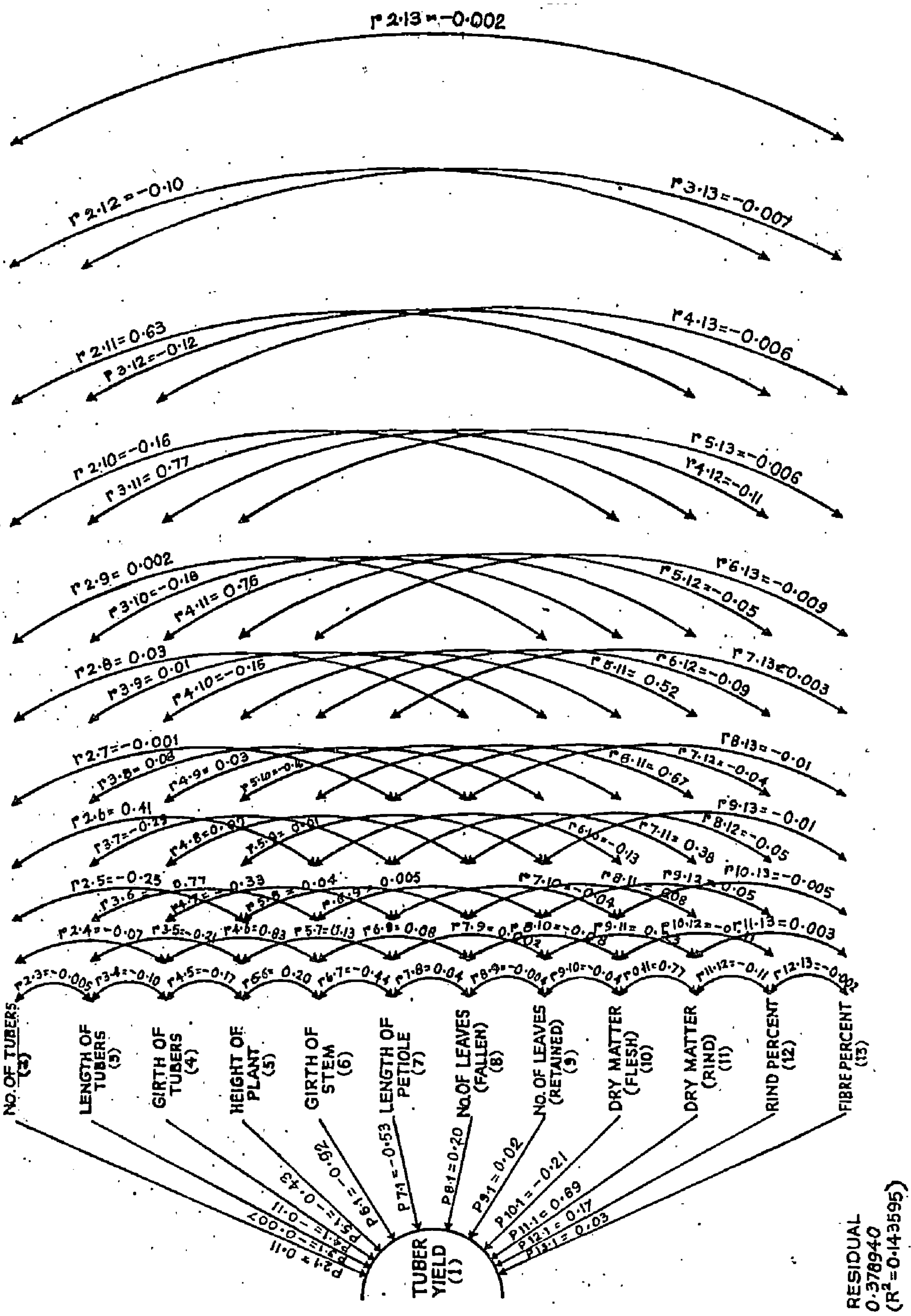
PATH DIAGRAM-3

SAND CULTURE EXPERIMENT-YIELD COMPONENTS (Y1)



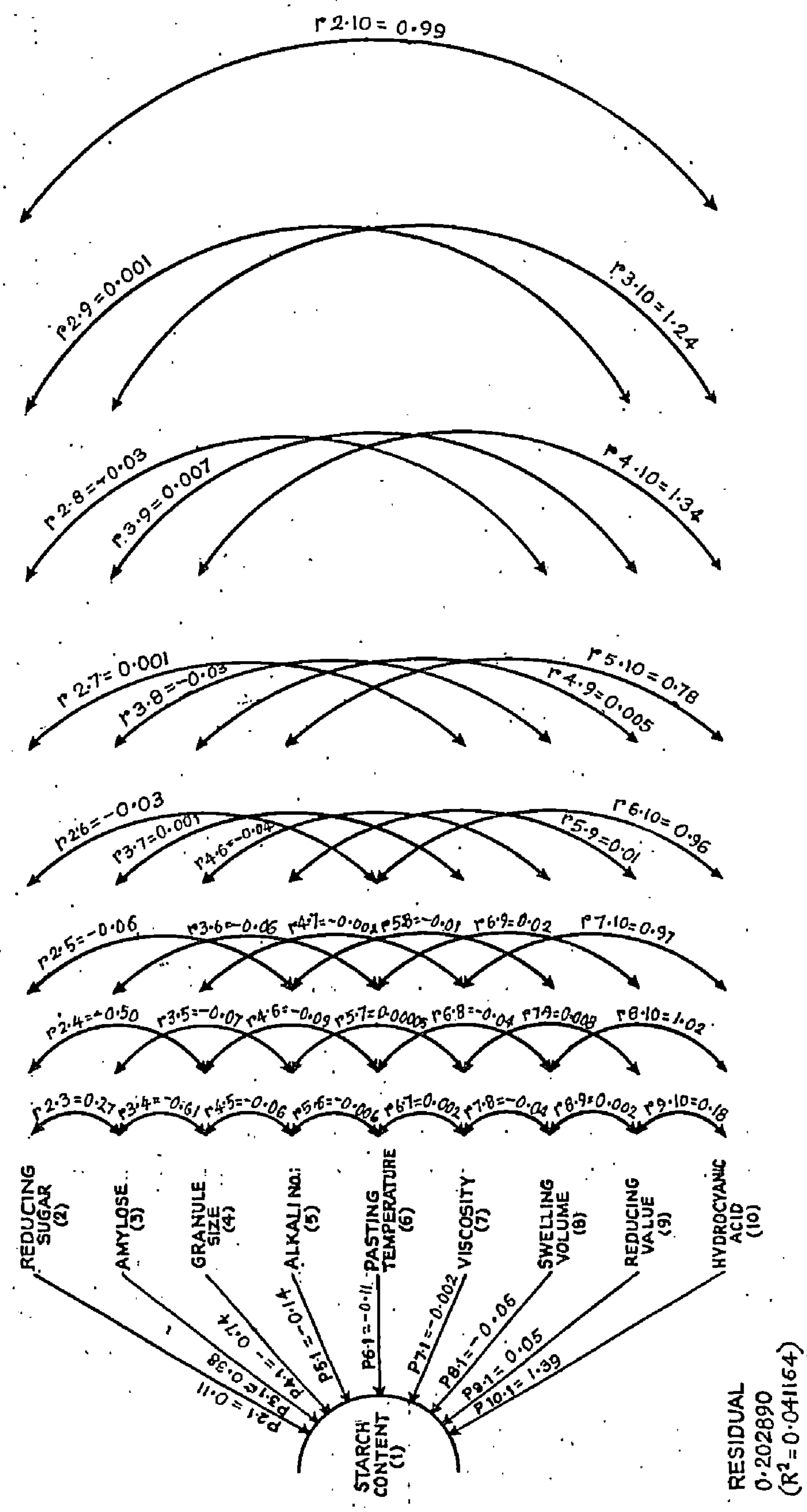
PATH DIAGRAM·4

SAND CULTURE EXPERIMENT-YIELD COMPONENTS (V_2)



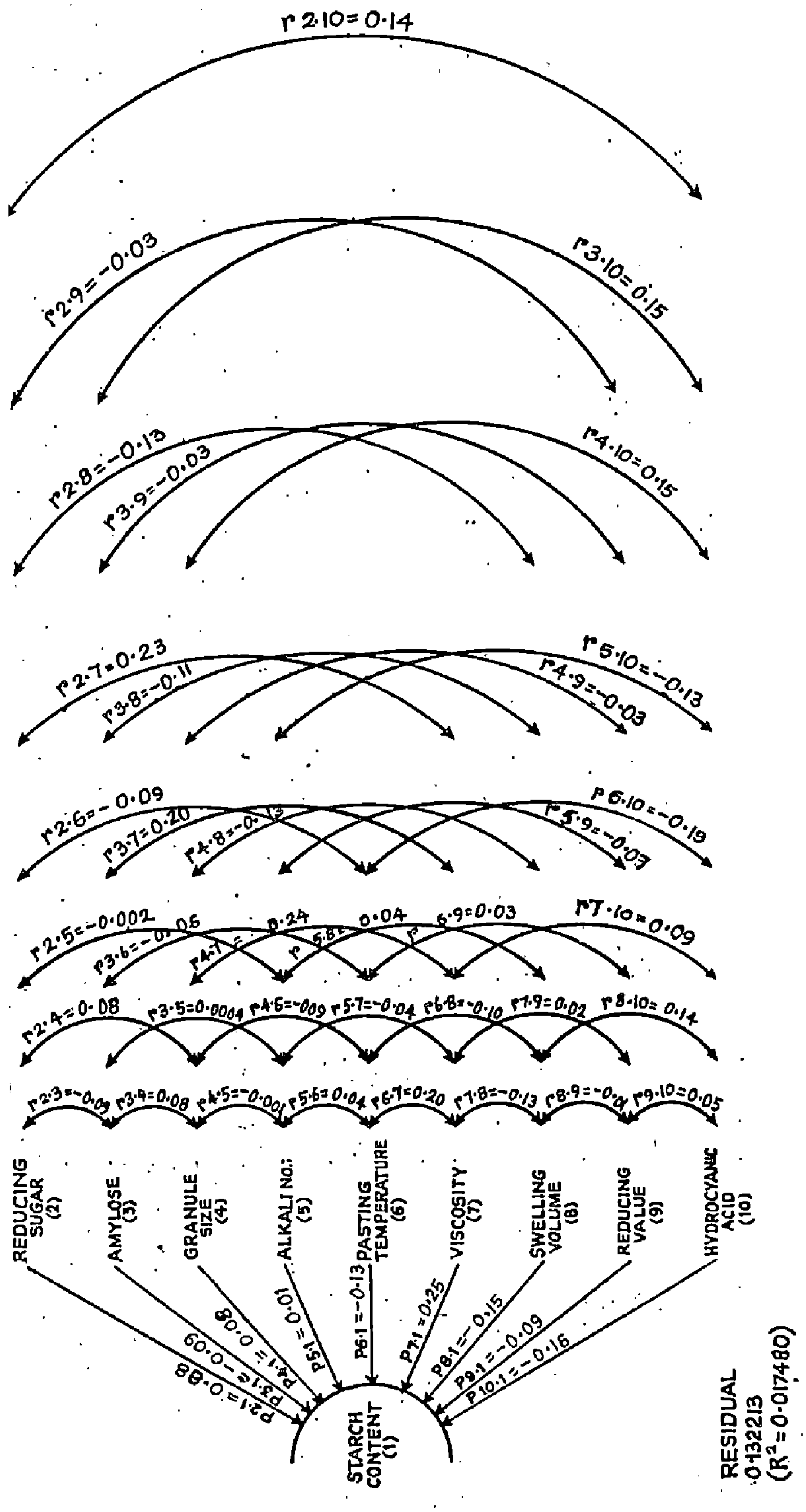
PATH DIAGRAM·5

FIELD EXPERIMENT-STARCH CHARACTERS (V_1)



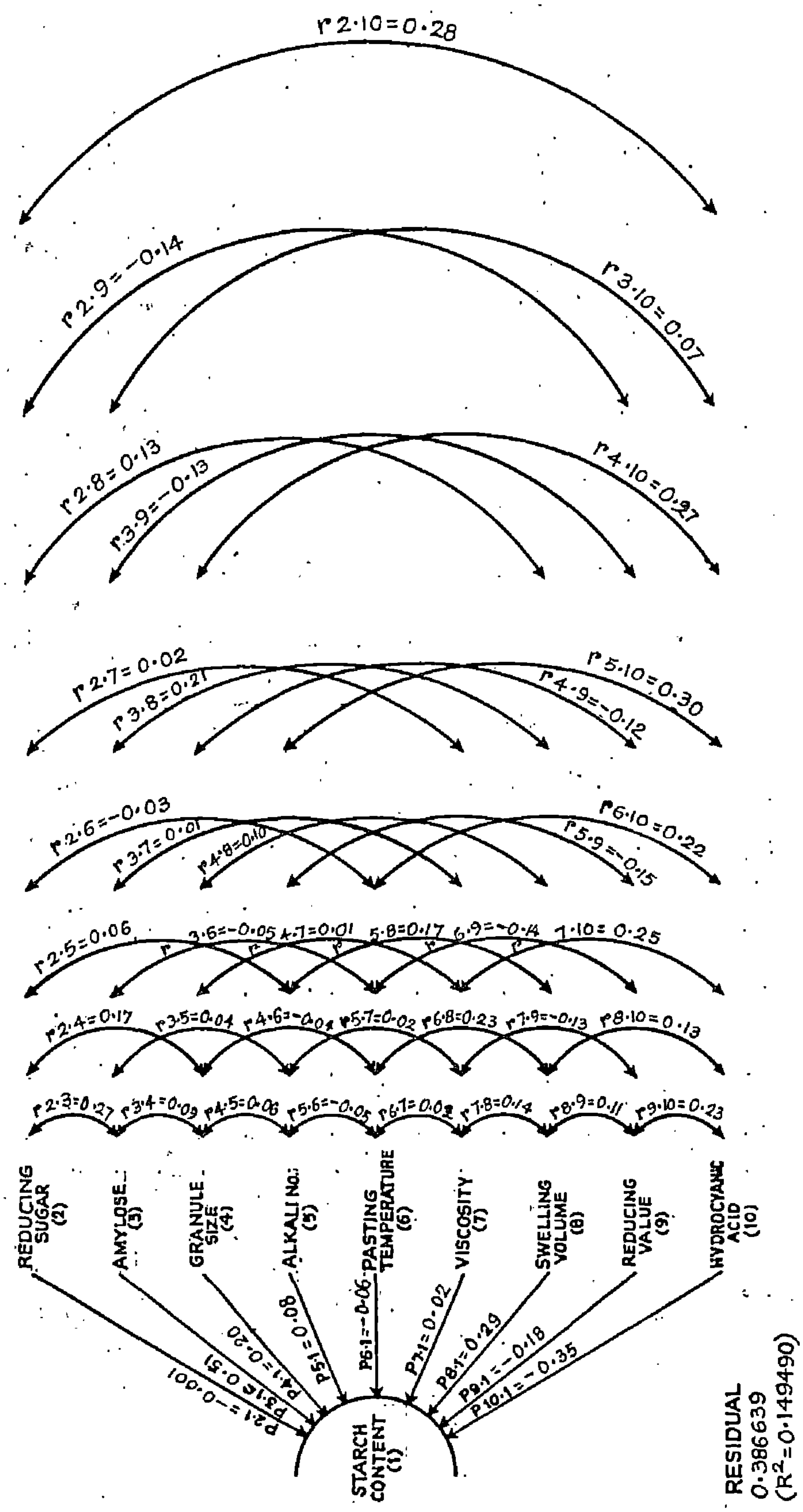
PATH DIAGRAM 6

FIELD EXPERIMENT- STARCH CHARACTERS (V_2)



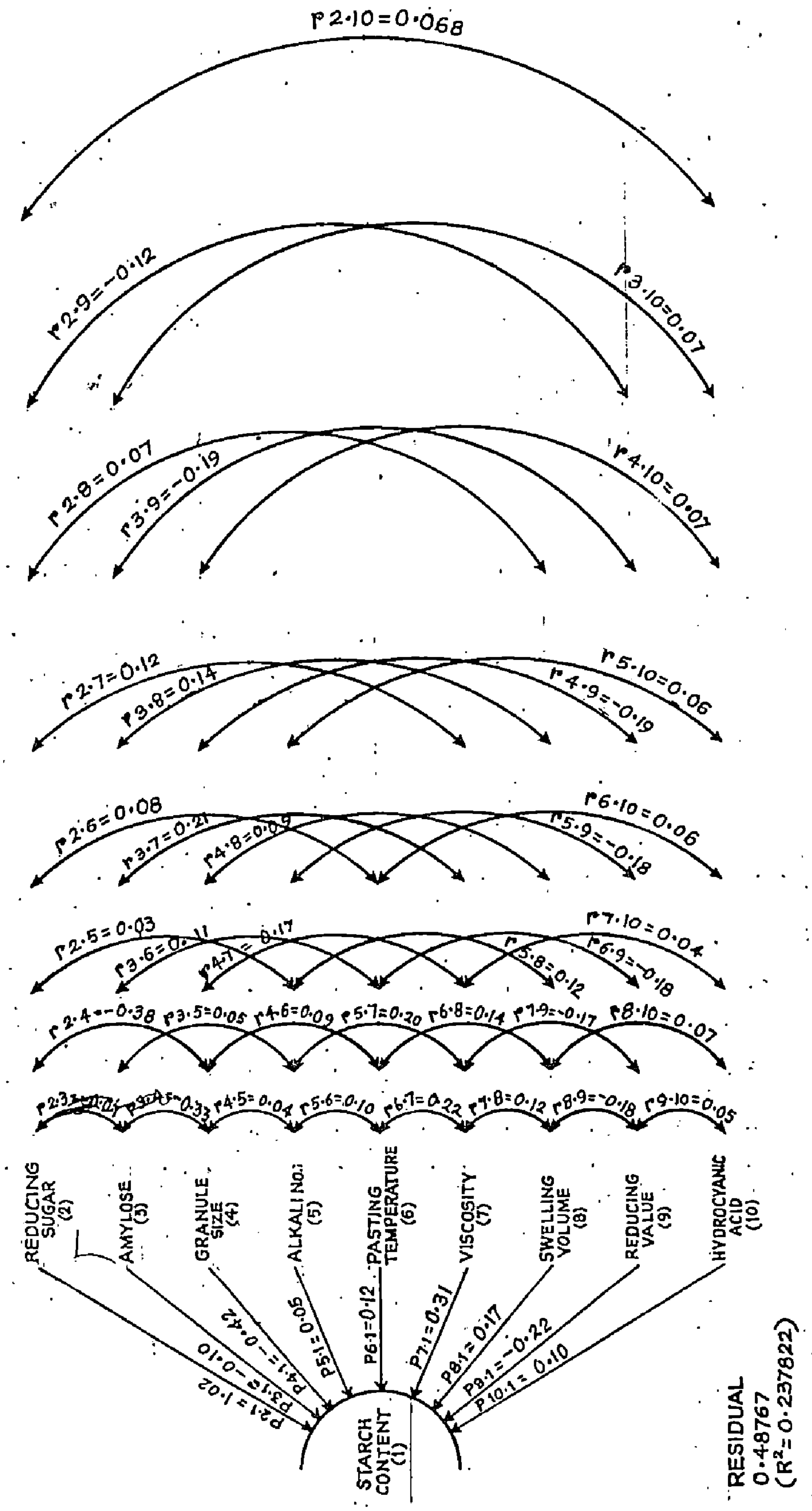
PATH DIAGRAM·7

SAND CULTURE EXPERIMENT- STARCH CHARACTERS (V1)



PATH DIAGRAM·8

SAND CULTURE EXPERIMENT·STARCH CHARACTERS (V2)



Soil characteristics and soil analysis

The soil of the experimental field was red loam (sandy loam as per textural classification) and was low in available potassium. The physical and chemical composition of the soil are presented in table 61.

Table 61. Soil characteristics of experimental field

A. Mechanical composition

1.	Clay	15.66 (per cent)
2.	Silt	20.18 (,,)
3.	Fine sand	21.50 (,,)
4.	Coarse sand	42.59 (,,)

B. Chemical composition

1.	Available nitrogen (N)	240.2 (kg/ha)
2.	Available phosphorus (P)	10.6 (,,)
3.	Available potassium (K)	190.9 (,,)
4.	pH (1:2.5 water suspension)	5.35
5.	Organic carbon	0.52 (per cent)
6.	Cation exchange capacity	6.8 (m.e./100 g soil)

The soil available K was estimated after each crop during the exhaustion process and the potash status of the soil is shown in table 62.

Table 62. Potash status of the experimental field during exhaustion crops

Plot No.	Soil available K (kg/ha)		
	Initial	After 1st crop	After 2nd crop
1	149	100	60
2	151	125	65
3	155	115	70
4	147	120	65
5	152	120	70
6	150	120	60
7	145	120	75
8	144	115	60
9	154	120	70
10	153	115	65
11	152	120	75
12	147	124	65
13	151	121	75
14	149	126	70
15	156	124	65
16	155	119	60
17	151	116	58
18	144	125	60
19	154	115	65
20	153	110	59
21	145	120	60
22	140	116	56
23	155	109	59
24	156	112	65
25	158	118	64
26	157	116	69
27	146	124	59
28	149	115	56

table continued

Plot No.	Soil available K (kg/ha)		
	Initial	After 1st crop	After 2nd crop
29	155	120	60
30	158	125	79
Mean	150	110.2	65.2

The total K status of the soil came down to 2324 and 2232.6 kg K/ha after the first and second exhaustion crops respectively from an initial level of 2300 kg K/ha.

After the two exhaustion crops of cassava intercropped with guinea grass, the soil available potash was brought to a very low level of available K i.e. 65.2 kg K/ha, before conducting the actual experiment. The different doses of potash (viz., 0, 50, 100, 150 and 200 kg K_2O/ha) were applied and the actual experiment was conducted. After the harvest of the experiment soil samples from different treatments were analysed for total and available potash contents and is presented in table 63.

Nutrient concentration in plant parts

1. Sand culture experiment

Potassium

The concentration of potassium in the leaf was estimated at 4th month and at the time of harvest (10th month) and is presented in table 64.

Table 63. Potash status of the soil in different treatments before and after the final crop

Treatments ($kg\ K_2O/ha$)	Available K (kg/ha)			Total K (kg/ha)		
	Initial	Final (after the crops)	Difference	Initial	Final (after the crop)	Difference
0	65.2	58.5	-6.7	2282.6	2265.8	-16.8
50	65.2	85.1	+19.9	2282.6	2279.6	-3.0
100	65.2	126.4	+61.2	2282.6	2335.2	+52.6
150	65.2	169.3	+104.1	2282.6	2366.4	+83.8
200	65.2	186.4	+121.2	2282.6	2394.5	+128.7

Table 64. Potassium content in leaf at different durations of K application

Durations of K application in months	Potassium content in leaf (per cent)			
	At 4th month		At harvest (10th month)	
	H-2304	M-4	H-2304	M-4
0 (Control)	0.45	0.38	0.41	0.35
0–1½	0.95	0.90	0.92	0.86
0–3	1.36	1.25	1.24	1.10
0–4½	2.32	1.98	2.05	1.74
0–10	2.64	2.35	2.28	1.99
4½–10	0.95	0.80	0.83	0.78
3–4½	1.20	1.05	0.98	0.87
1½–3	1.52	1.38	1.53	1.26
1½–4½	1.25	1.10	1.11	0.98

C.D. at 0.05 for V = 0.1215 0.0986

" T = 0.2014 0.1452

The uptake of potassium by cassava at different durations of K-application was calculated and is presented in table 69. The variation of yield and potassium uptaken at different durations of K-application is shown in Fig.3. It can be seen from the figure that the yield and potassium uptake do not follow a similar pattern for both the varieties viz., H-2304 and H-4. Eventhough the maximum yield is for 0-4½ months duration of K-application, the maximum uptake is for 0-10 months duration.

Table 69. Uptake of potassium at different durations of its application

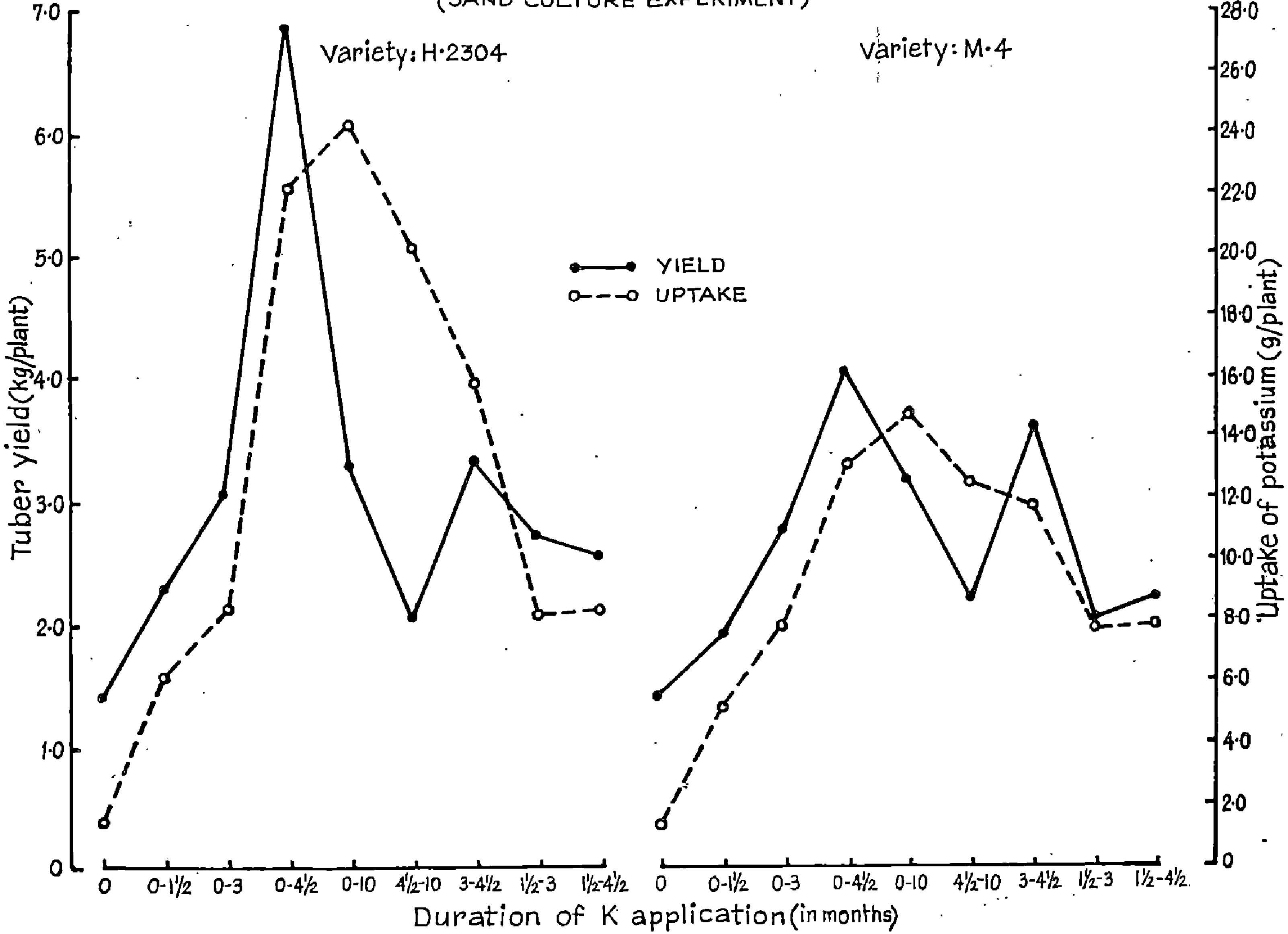
Duration of K application in months	Uptake of K			
	H-2304		H-4	
	(g/plant)	(kg/ha)	(g/plant)	(kg/ha)
0	1.49	18.39	1.26	15.55
0-1½	6.34	78.27	5.22	64.44
0-3	8.49	104.81	7.80	96.29
0-4½	22.72	276.09	13.95	161.10
0-10	24.49	301.59	14.77	182.34
4½-10	20.27	250.23	12.52	154.56
3-4½	15.91	196.41	11.79	145.55
1½-3	8.33	102.83	7.75	95.67
1½-4½	8.55	105.55	7.90	98.51

C.D. at 0.05 for V = 0.1447
" " T = 0.3070
" " V x T = 0.1772

The variation in the uptake of potassium and yield at different durations of K application is shown in Figure 3.

Fig.3

VARIATION IN YIELD AND POTASSIUM UPTAKE
(SAND CULTURE EXPERIMENT)



It can be noted from the figure that the uptake of potassium and yield do not follow a similar pattern. While the maximum yield is for 0-4½ months duration of K-application, the maximum uptake of potassium corresponds to 0-10 months duration of its application.

The uptake of nitrogen and phosphorus was computed from the concentration of these elements in different plant parts viz., leaf, stem and tuber and is presented in table 66.

Table 66. Uptake of nitrogen and phosphorus at different durations of potassium application

Durations of K application in months	Uptake of N (kg/ha)		Uptake of P (kg/ha)	
	K-2304	K-4	K-2304	K-4
0	81.29	76.48	22.55	21.13
0-1½	104.44	93.64	24.68	23.24
0-3	129.06	102.32	25.72	24.88
0-4½	150.61	110.56	29.81	26.52
0-10	121.72	100.08	26.62	25.31
4½-10	110.12	96.24	24.49	24.22
3-4½	103.38	92.53	23.38	23.81
1½-3	103.95	85.46	23.24	23.18
1½-4½	104.69	86.31	22.85	22.34

C.D. at 0.05 for N = 5.3281
" " P = 4.2178

The average concentration of N, P and K in different plant parts, fresh matter distribution and dry matter percentage are presented in table 67.

Table 67. Average concentrations of N, P and K in different plant parts

Nutrients	Concentration (%) Leaf	Petiole	Stem	Tuber
Nitrogen (N)	4.25	1.36	0.72	0.34
Phosphorus (P)	0.28	0.15	0.25	0.12
Potassium (K)	1.85	2.31	1.72	0.92
Fresh matter distribution (%)	12.8	7.3	29.6	50.4
Dry matter (%)	25.1	24.9	25.2	34.8

Potassium deficiency

Deficiency of potassium was characterised mainly by a severe reduction in plant height, stem girth and short petioles and small leaves (Photograph 1 and tables 32, 34 and 35). Only in the case of zero potash treatment specific symptoms of potassium deficiency was noticed. In the early stages viz., on 4th week small purple spots appeared on lower (older) leaves and curling of leaf margins occurred. As the deficiency intensified, chlorotic areas developed at the tips and along the margin of the leaves and joined upto form a border necrosis. Older leaves and petioles fell prematurely. There was a brown discoloration on the petioles. The youngest fully expanded leaves (YFEL) collected from potassium deficient plants

Plate 1. K - DEFICIENT and HEALTHY CASSAVA LEAVES

Plate 2. CASSAVA TUBERS IN K_0 and K_{100} TREATMENTS

were analysed for their K content. Simultaneously leaves (YFEL) collected from normal, healthy plants with added K upto 4½ months were also analysed for their K content. The results are presented in table 68.

Table 68. Concentrations of youngest fully expanded leaf blades of cassava at 3rd month stage

K levels in YFEL at third month stage Deficient (in plants with deficiency symptoms)	Normal (in healthy plants)
0.38 - 0.90%	0.90 - 2.36%

2. Field experiment

Potassium

The concentration of potassium in the leaf was estimated at 4th month and at the time of harvest and is shown in table 69.

Table 69. Potassium content in leaf at different levels of K_2O

Levels of K_2O (kg/ha)	K content in leaf (%)			
	At 4th month		At 10th month (harvest)	
	H-2304	M-4	H-2304	M-4
0	0.95	0.91	0.93	0.90
50	1.26	1.10	1.18	1.05
100	1.75	1.62	1.61	1.48
150	1.98	1.66	1.79	1.66
200	2.36	2.24	2.25	2.18

C.D. at 0.05 for T = 0.2140

From the table, it can be noted that the percentage of potassium in the leaf increases as the levels of potassium increase.

The relationship between yield and concentration of potassium in the leaf is shown in Figure 8. The critical value of potassium for both in varieties viz., K-2304 and K-4 is found to be quadratic. The functions are:-

(1) $Y = -1.7306 + 4.09978\,K + 1.31269\,K^2$ (for variety K-2304)

(2) $Y = -1.1255 + 3.4229\,K + 0.93316\,K^2$ (for variety K-4)

The critical value of potassium in the leaf (YFEL) blade is K = 1.866 per cent (for variety K-2304) and K = 1.834 per cent (for variety K-4) at 4th month stage.

The relationship between tuber yield and levels of potassium is represented in Figure 7. It can be seen that as the level of potassium increased beyond 100 kg K_2O/ha, the yield gradually declines. Response curves were fitted and it was seen that the response of tuber yield to potassium was quadratic. The two functions obtained are

(1) $Y = 21.342 + 0.21824\,K - 0.000843\,K^2$ (for variety K-2304)

(2) $Y = 13.7178 + 0.21376\,K + 0.0000465\,K^2$ (for variety K-4)

Thus, the maximum level for highest yield is found to be 129.44 kg K_2O/ha for variety K-2304 and 126.26 kg

Fig·4

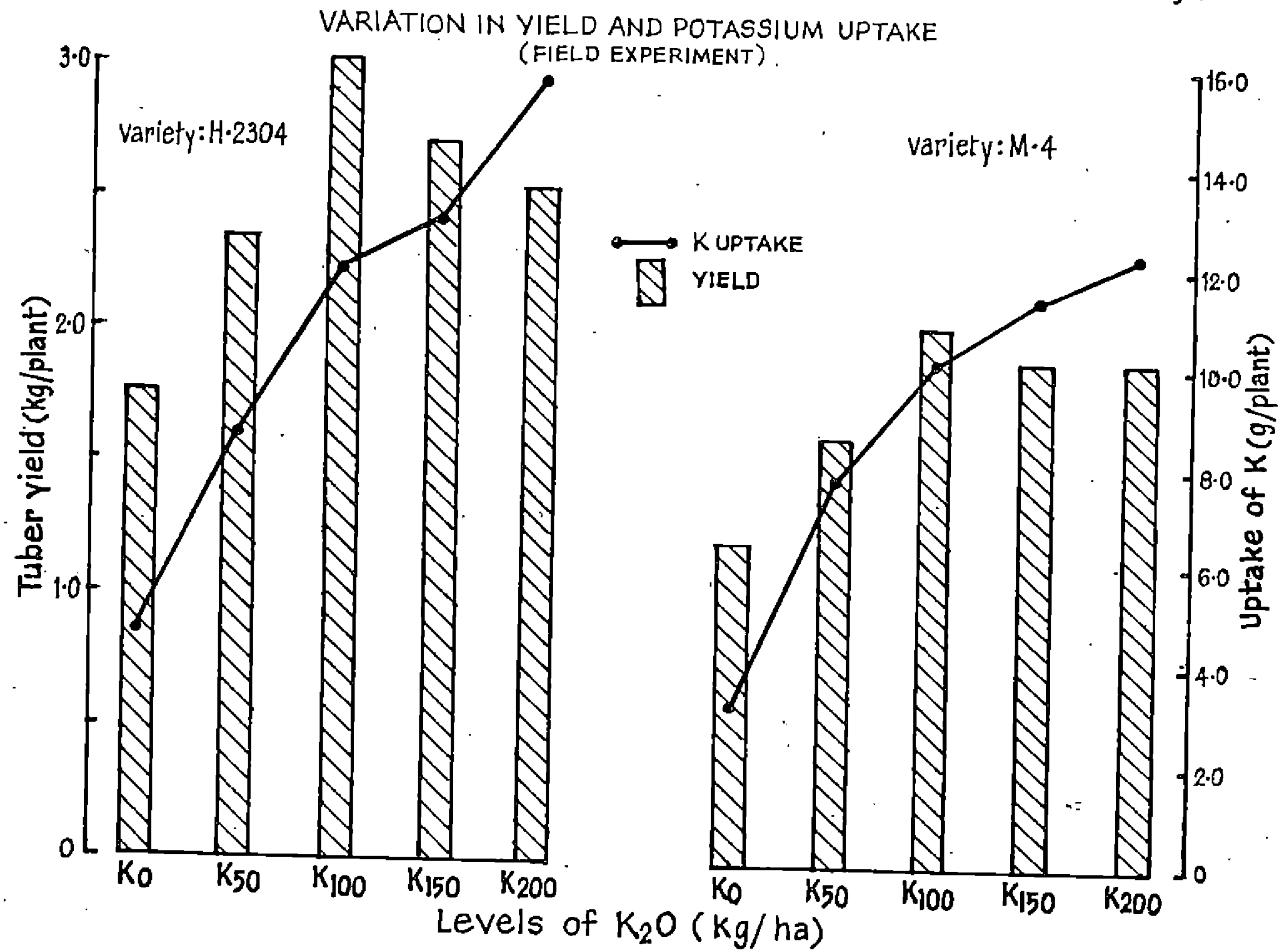
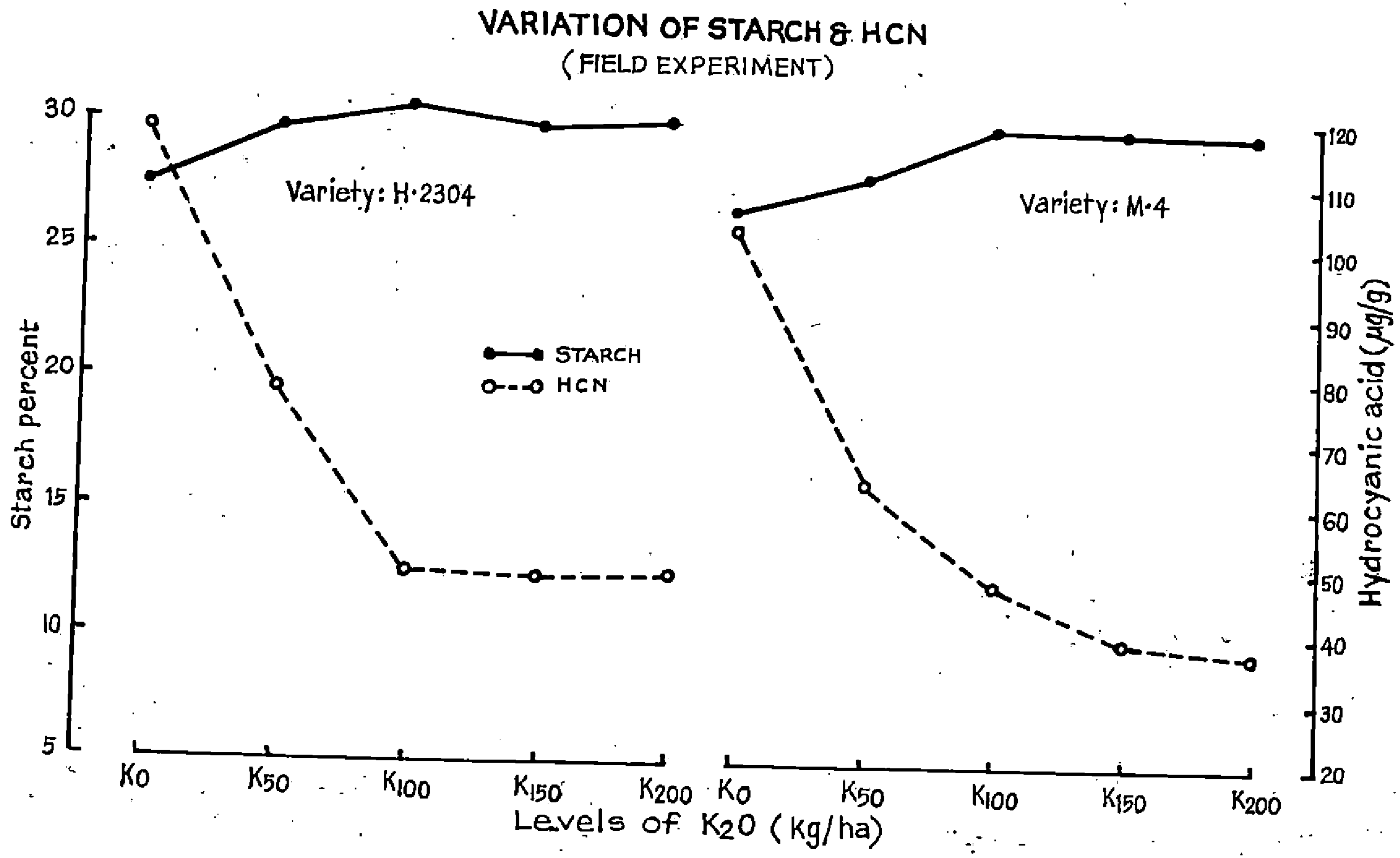
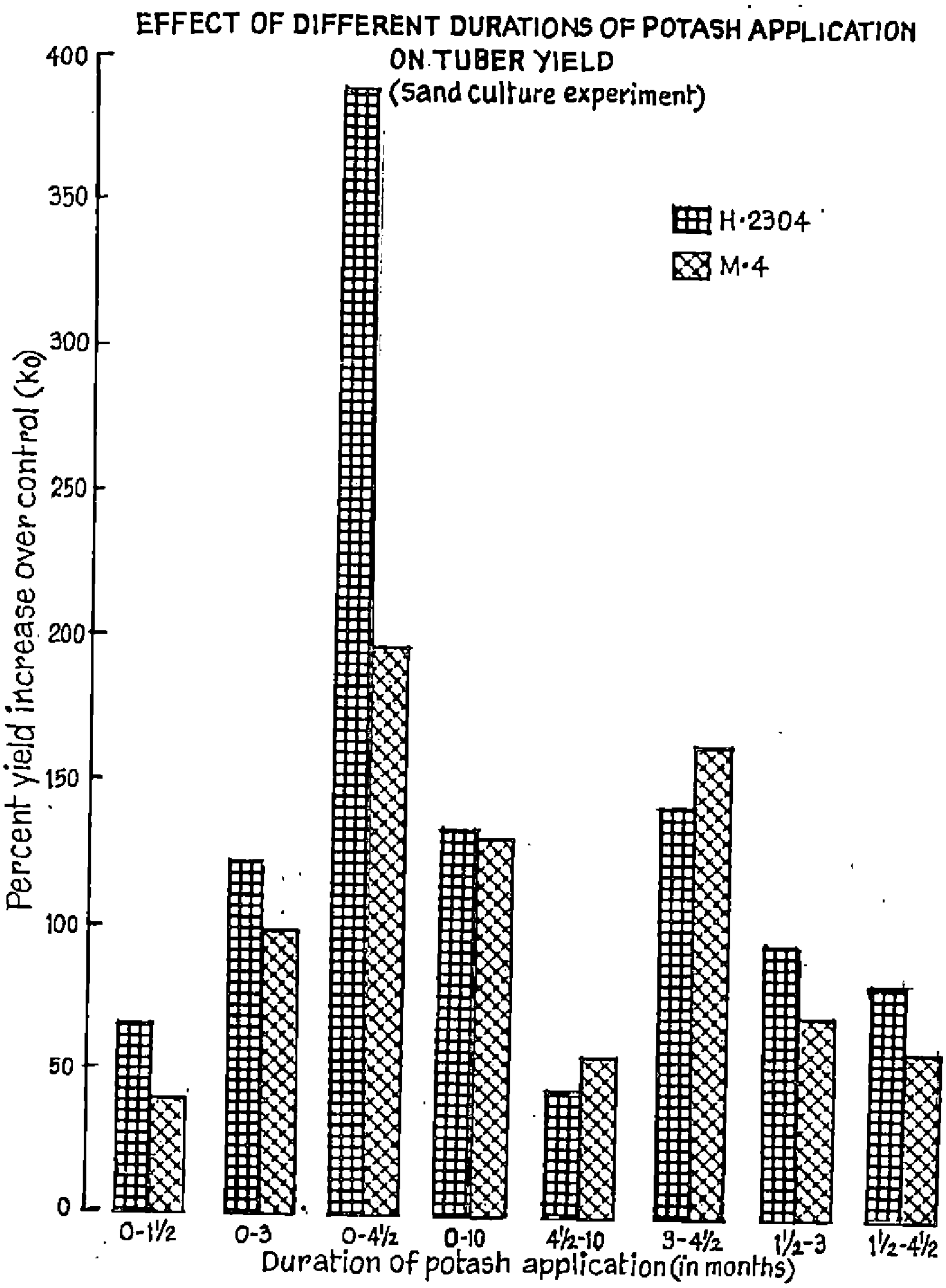

VARIATION IN YIELD AND POTASSIUM UPTAKE
(FIELD EXPERIMENT)
Variety: H·2304
Variety: M·4
K UPTAKE
YIELD
Tuber yield (kg/plant)
Uptake of K (g/plant)
3·0
2·0
1·0
0
16·0
14·0
12·0
10·0
8·0
6·0
4·0
2·0
0
K0
K50
K100
K150
K200
Levels of K2O (Kg/ha)

Fig.5



VARIATION OF STARCH & HCN
(FIELD EXPERIMENT)
Variety: H·2304
Variety: M·4
STARCH
HCN
Starch percent
Hydrocyanic acid (μg/g)
30
25
20
15
10
5
120
110
100
90
80
70
60
50
40
30
20
K0
K50
K100
K150
K200
Levels of K2O (kg/ha)

Fig·6


EFFECT OF DIFFERENT DURATIONS OF POTASH APPLICATION ON TUBER YIELD
(Sand culture experiment)
H·2304
M·4
Percent yield increase over control (kg)
400
350
300
250
200
150
100
50
0
0-1½
0-3
0-4½
0-10
4½-10
3-4½
1½-3
1½-4½
Duration of potash application (in months)

Fig·7

RESPONSE OF TUBER YIELD TO POTASSIUM
(FIELD EXPERIMENT)

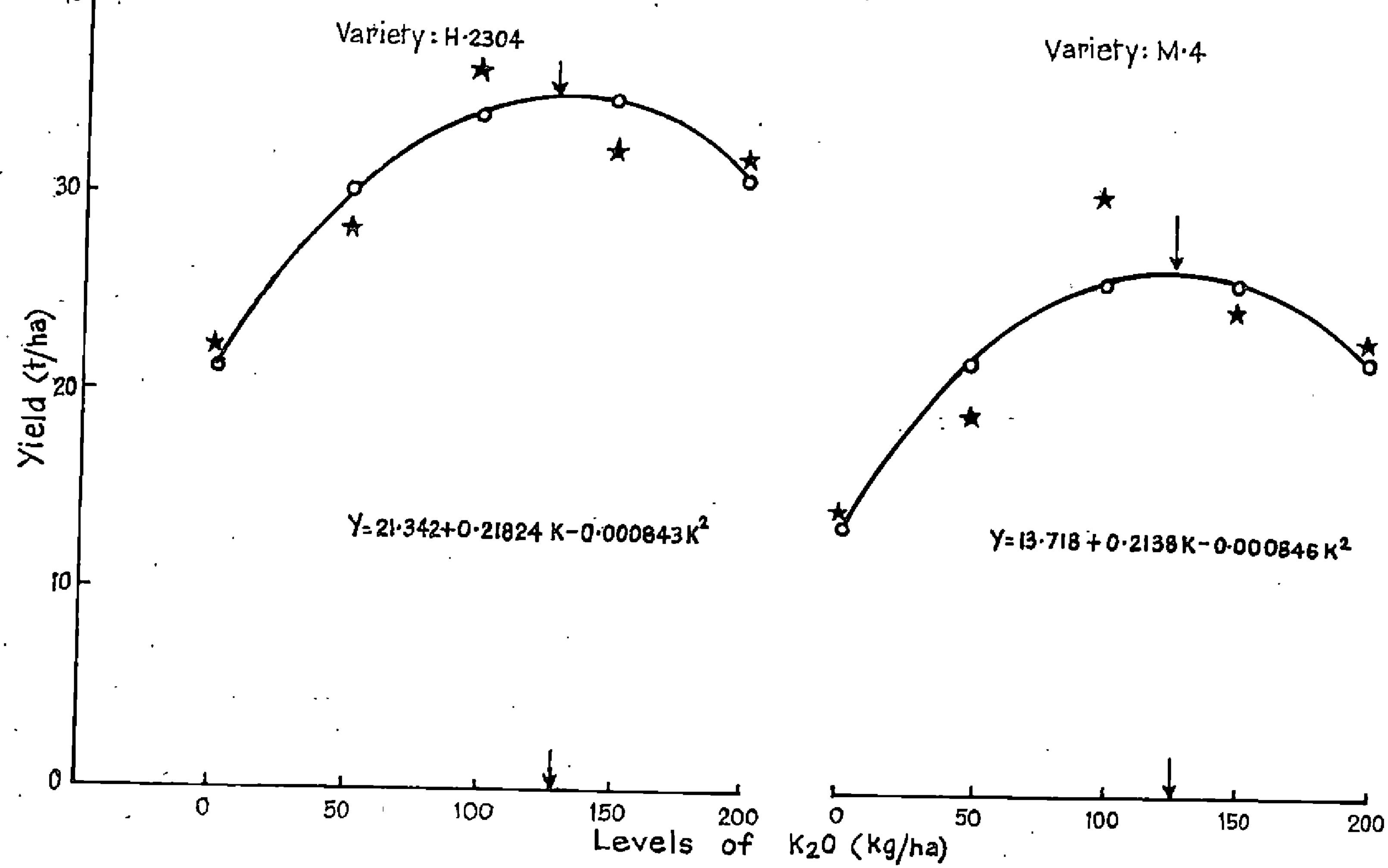
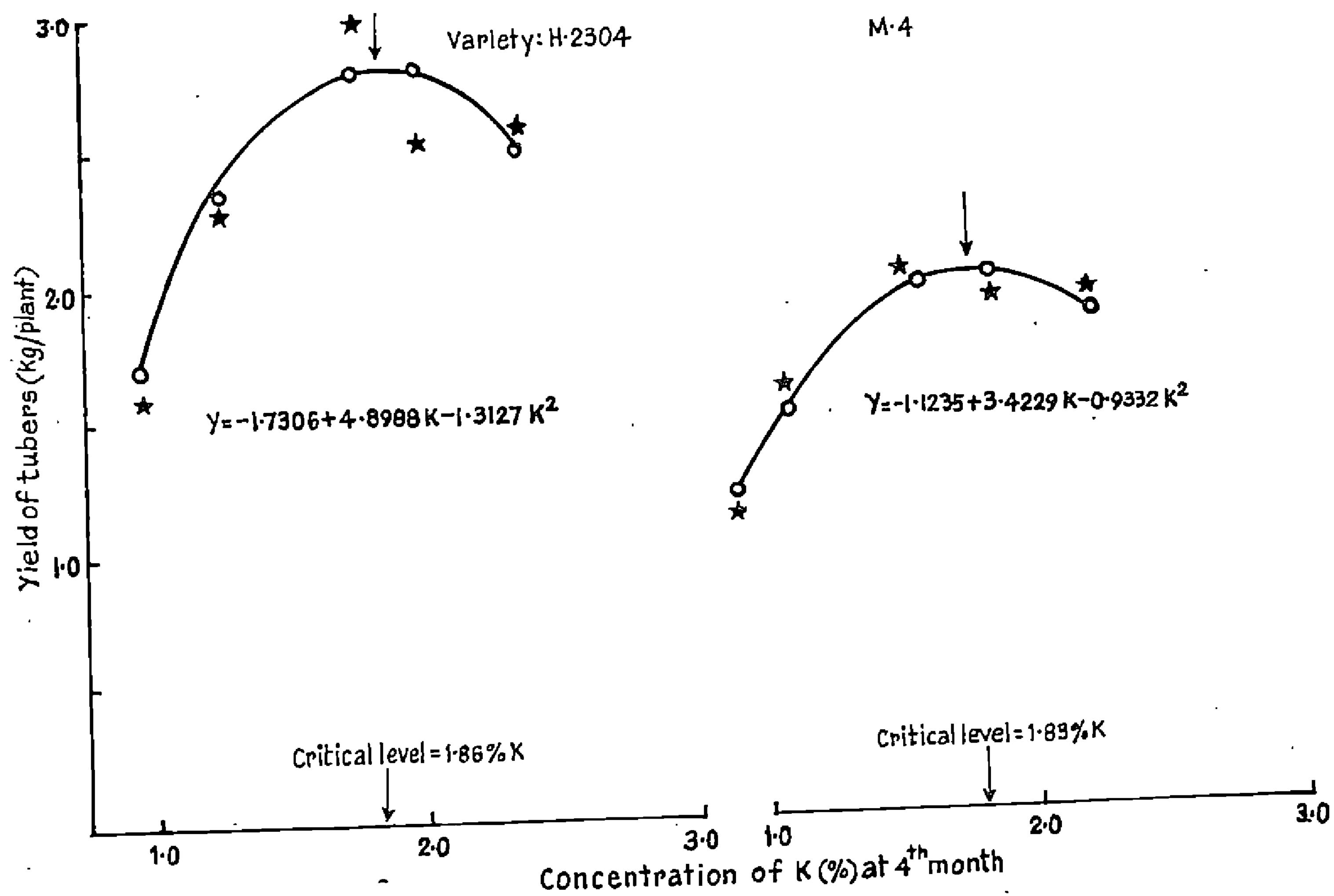


Fig.8

RELATIONSHIP BETWEEN YIELD AND CONCENTRATION OF K IN CASSAVA LEAF



K_2O/ha for variety M-4.

The uptake of potassium by cassava at different levels of K_2O was calculated from concentration of potassium in different plant parts and is presented in table 70.

Table 70. Uptake of K by cassava at different levels of potassium

Levels of K_2O (kg/ha)	Uptake of K			
	H-2304		M-4	
	(g/plant)	(kg/ha)	(g/plant)	(kg/ha)
0	4.50	55.55	3.28	40.49
50	8.52	105.17	7.73	95.43
100	11.81	145.67	10.17	125.55
150	13.00	160.40	11.60	143.20
200	15.84	195.05	12.22	150.05

C.D. at 0.05 for V = 0.2078

" T = 0.3285

" V x T = 0.2545

It can be noted from the table that the uptake of K increases as the levels of K_2O increase. The relationship between tuber yield and uptake of K by cassava is presented in Figure 4. It can be seen from the figure that the tuber yield increases upto a level of 100 kg K_2O/ha and beyond that it decreases. But the uptake of K goes on increasing as the levels of potassium increase.

The concentrations of K in different plant parts viz., leaf, petiole, stem and tuber and the dry matter content of tuber were estimated at different levels of K_2O and the average values are presented in table 71.

Table 71. Average concentrations of K in different plant parts and dry matter content of tuber at various levels of potassium

Levels of K_2O (kg/ha)	Concentration of K (%)				Dry matter per cent in tuber (%)
	Leaf	Petiole	Stem	Tuber	
0	0.95	1.42	0.78	0.72	36.60
50	1.26	1.64	0.92	0.81	37.05
100	1.75	1.95	1.15	0.96	43.07
150	1.98	2.28	1.28	1.05	39.14
200	2.36	2.42	1.56	1.10	40.04

The uptake of N and P were computed at different levels of K from plant analysis and the average values are presented in table 72.

Table 72. Uptake of N and P at different levels of potassium

Levels of K_2O (kg/ha)	Uptake of N (kg/ha)			Uptake of P (kg/ha)		
	N-2304	N-4	Mean	N-2304	N-4	Mean
0	108.69	102.41	105.55	25.24	24.82	25.03
50	112.52	106.82	109.67	24.89	25.21	25.05
100	115.41	107.45	111.43	26.65	25.82	26.24
150	120.13	108.52	114.33	24.24	24.63	24.44
200	122.33	108.84	115.58	27.16	25.42	26.29

N.S.

The effect of different levels of potash application on utilisation index was calculated and is shown in table 73.

Table 73. Effect of various levels of potash on utilisation index

Levels of K_2O (kg/ha)	Utilisation index		
	H-2304	H-4	Mean
0	2.05	1.78	1.92
50	2.18	1.85	2.02
100	2.20	1.89	2.05
150	2.19	1.92	2.05
200	2.25	1.95	2.10

N.S.

Potassium nutrition and spider mite (*Eutetranychus orientalis* Klein) infestation in cassava

The number of spider mite infested leaves in the field experiment, at different levels of potassium was assessed at the time of harvest, a period when maximum mite infestation was noticed. The results are presented in table 74.

From the table it can be seen that the varieties are significantly different from each other. The incidence of spider mite is more in variety H-4 when compared to variety H-2304. Eventhough the per cent of mite infested leaves generally decrease as the levels of potassium increase, the significant reduction is only upto 100 kg K_2O/ha.

Table 74. Extent of spider mite incidence at different levels of potassium

Varieties	Per cent of mite infested leaves					Mean
	K_0	K_{50}	K_{100}	K_{150}	K_{200}	
H-2304	52.76	35.77	22.85	20.70	19.90	29.99
M-4	52.75	33.77	29.30	26.80	27.53	34.03
Mean	52.75	33.77	26.07	23.75	23.72	

C.D. at 0.05 for V = 2.0639
" " K = 3.263

Cooking quality of tubers

The cooking quality of tubers under various levels of potassium was assessed as per the method of Prema *et al.* (1975). Both the varieties viz., H-2304 and M-4 were boiled for 30 minutes after removing the rind, washing and cutting into pieces. Then water was drained and taste assessed by a panel of 15 rural people. Taste was measured on a discrete scale with 5 points. The best taste was allotted a score of 4 and the others were allotted 3, 2, 1 and 0 in decreasing order of taste. The members of the panel of tasters were served freshly cooked cassava in a random order. After each sample, the taster was asked to write down his/her judgement in terms of the five levels of taste specified. The mean scores obtained by the two varieties at different levels of K in the organoleptic test are presented in table 75.

Table 75. Mean scores obtained in the organolyptic test of tubers at different levels of K

Treatments	H-2304	M-4	Mean
K_0	1.25	2.86	2.06
K_{50}	2.06	2.95	2.51
K_{100}	3.12	3.45	3.29
K_{150}	3.23	3.52	3.38
K_{200}	3.30	3.65	3.48

C.D. at 0.05 for V = 0.2534

" " T = 0.1468

Discussion

DISCUSSION

SAND CULTURE EXPERIMENT

1. Yield of tubers

Table 5 and Fig.3 present the data on the yield of tubers of the two varieties H-2304 and M-4 under different treatments viz., different durations of supply of potash. The maximum yield obtained is for treatment number four (T_4), wherein potassium was supplied from the time of planting upto 4½ months. Asokan and Sreedharan (1977, 1978 and 1980) obtained maximum yield when potash was applied as 3 splits viz., 1/3 as basal + 1/3 at 2 months + 1/3 at 3 months for cassava variety H-97. The similar results were reported by Natarajan (1975), Asokan et al. (1980), Sheela (1981), Nair (1982) and Asokan Vikraman (1983). Kumar and Nair (1969) reported that the maximum uptake of potassium by cassava was by the 4th month. Zero potassium (control) recorded the lowest yield. Boop (1937) found that three successive cassava plantings without K application decreased yields from 15 to 4 t/ha. Malvolta et al. (1959) found that when K was omitted from nutrient solution the yield of tubers decreased in cassava. Natarajan (1975), Pushpadas and Aiyer (1976), Asokan et al. (1980), Sheela (1981) and Nair (1982) also reported that in zero potash control plots the yield of tuber in cassava was considerably reduced. Variety H-2304 recorded significantly higher yields than variety M-4 which may be attributed to varietal character. This is in agreement with the results of Potty and Asokan (1980) and Nair (1982).

2. Number of tubers

Data presented in table 6 reveal the significant effect of potash nutrition in the production of number of tubers in cassava. In cassava, tuber number is considered as an important yield component. Results of the sand culture experiment show that the period at which potassium is supplied from 0-4½ months (T_4) has registered highest number of tubers. Nair (1982) also reported an increase in tuber number when potash was applied @ 200 kg K_2O/ha. For efficient photosynthesis by leaves adequate supply of potassium is essential (Russel, 1973). This also explains higher number of tubers in plots receiving adequate potassium supply. Pushpadas and Aiyer (1976) reported increase in tuber number at higher levels of potassium in cassava varieties M-4 and H-105. Number of tubers are significantly higher in H-2304 than in M-4. This may be a varietal character.

3. Length and girth of tubers

Table 7 and 8 presents data on the average length and girth of tubers per plant. Treatments involving potassium nutrition from 0-4½ months (T_4) recorded significantly greater mean length and girth of tubers than other treatments. Control with zero potassium recorded lowest length and girth of tubers. Variety H-2304 is significantly superior to M-4 as far as length and girth of tubers are concerned. Magoon et al. (1972), studying the characters of F_1 populations of some cassava cultivars found that there was a positive correlation between tuber length and tuber girth on one side and yield of tubers on the other. In the present study also maximum length and girth of tubers is recorded by treatment with K nutrition for 0-4½ months, which gives the highest yield.

4. Height of plants

The data on mean height of plants is presented in table 9. Treatments involving potash nutrition for 0-4½ months (T_4), 0-3 months (T_3), 0-10 months (T_5) and 1½-4½ months (T_9) are significantly superior to other treatments and are in a decreasing order. Control with no added potassium (T_1) and plants which received potassium for 3-4½ months only (T_7) recorded lowest height. Magoon et al. (1972) reported positive correlation of plant height in cassava with tuber yield. In the present study treatment involving potash nutrition for 0-4½ months records maximum height as well as highest yield. Variety M-4 records significantly higher plant height than variety H-2304. This may be due to the fact that M-4 is a non-branching erect type when compared to H-2304.

5. Girth of stem

The average girth of stem at the base is presented in table 10. Treatments involving potash nutrition for 0-4½ months (T_4), 1½-3 months (T_8), 0-10 months (T_5) and 0-3 months (T_3) are significantly superior from remaining treatments including control. There is no definite trend as far as girth of stem is concerned eventhough potash nutrition for 0-4½ months records maximum tuber girth. Ramanujam and Indira (1980) also found no relationship of stem girth with yield. Variety H-2304 records significantly higher stem girth than variety M-4 generally. This may be a varietal character.

6. Length of petiole

Table 11 presents data on the length of petiole at the time of harvest. Treatments involving potash nutrition for 0-4½ months (T_4) and 0-10 months (T_5) are superior to other treatments including control. Again T_4 is significantly superior to T_5. Remaining treatments occupy intermediary values. The control i.e. zero potash (T_1) is significantly lowest. Asher *et al.* (1980) also observed that in potassium deficient cassava plants there is severe reduction in petiole length.

7. Total number of leaves produced

The total number of leaves produced in the sand culture experiment is presented in table 12. Potash nutrition for 0-4½ months (T_4) gave the highest leaf number, but this was on a par with treatment involving nutrition with potash for 0-3 months (T_3), 1½-3 months (T_8), 1½-4½ months (T_9) and 0-10 months (T_5). Nair (1982) found that potassium levels showed significant effect on top yield only upto 125 kg K_2O/ha. They also reported the lesser influence of potassium on vegetative growth. Lakshmi and Easwari Amma (1980) found a positive significant association of number of leaves and tuber yield in

Dioscorea. Thamburaj (1976) reported positive relationship between yield and weight of foliage in sweet potato. In the present study, control with zero potash (T_1) gave significantly lowest leaf number which indicates the effect of potassium on top growth. For efficient utilization of photosynthates, it should be translocated from the 'source' to the 'sink'. If the sink (yield) is high the source (photosynthate) also should be high. This explains why greater number of leaves is associated with treatments recording higher yields. Variety H-2304 produced generally greater number of leaves than variety H-4 which may be a varietal character.

8. Number of leaves retained and shed

Table numbers 13 and 14 present data on the number of leaves (expressed as per cent of total leaves) retained at harvest and those shed before harvest. It can be seen the highest per cent of leaves retained and naturally the lowest per cent of leaves shed is in treatment T_4 which received potassium for 0-4½ months only. The next treatment in descending order is T_3 which received potassium nutrition for 0-3 months. The control treatment (zero potassium) recorded minimum leaf retention and maximum leaf shedding per cent. This clearly shows that potassium has got a beneficial effect in leaf retention capacity. Where potassium is supplied adequately, leaf retention will be more. This may be due to the fact that potassium fertilization increased tolerance to water stress in plants (Edwards, 1982).

9. Dry matter content of flesh in tubers

Table 15 presents data on the variation of dry matter content of flesh in tuber as influenced by potassium supply for different periods in the sand culture experiment. The dry matter is maximum in the treatment in which potash was supplied for 0-4½ months (T_4) and it is significantly superior to all other treatments. Dry matter is minimum in control (T_1) where no potash was given. Thamburaj and Shanmugavelu (1980) also found that dry matter content of flesh was higher in plants with higher yield and starch content. Variety M-4 is significantly superior to variety H-2304 in respect of dry matter of flesh. This may be a varietal character.

10. Dry matter content of rind

The variation in dry matter content of rind under different periods of potash nutrition is presented in table 16. The dry matter content of rind is also maximum in the treatment in which potash was supplied for 0-4½ months (T_4). The dry matter of rind is minimum in zero potash treatment (T_1) and it is not significantly different from potash application for 0-1½ months (T_2). Maini and Balagopal (1978) also reported higher dry matter content of rind in good quality tubers when compared to deteriorated tubers. There is no significant difference between variety M-4 and variety H-2304 as far as dry matter of rind is concerned.

11. Rind content of tuber

Table 17 presents data on the rind content of tubers under different durations of potassium nutrition in the sand culture experiment. In the zero potash (T_1) rind per cent is maximum and in treatment T_4 where plants received potash for 0-4½ months only, it is minimum. The rind per cent in variety H-2304 is significantly lower than variety M-4. Emilia Abraham et al. (1980) found lesser rind content in varieties having more starch content. In this study also it was observed that rind per cent and starch content are negatively correlated.

12. Fibre content of tubers

The variation in fibre content of tubers due to different durations of potash supply is recorded in table 18. The control treatment (T_1) with no potash records maximum fibre content. Treatment which received potash for 0-4½ months (T_4) records minimum fibre content which is not significantly different from plants receiving potash for 0-3 months (T_3). This may be due to the fact that when potassium is supplied for the proper duration, the total starch content and flesh content increases and hence the per cent of fibre decreases. Fibre content in variety M-4 is significantly lower than variety H-2304. This may be a varietal character.

13. Starch content of tubers

Table 19 presents data on the starch content of tubers due to different durations of potash application in the sand culture experiment. Treatment which received potassium for

0-4½ months (T_4) records maximum starch content, which is not significantly superior to plants which received potash for 0-10 months (T_5) and is next in descending order. Treatments which received potash nutrition for 4½-10 months (T_6) and zero potash (T_1) are recording lowest starch content and are themselves in a descending order. Asokan and Vikraman (1983) and KAU (1981-82) report best results of potash application as three splits i.e. 1/3 as basal + 1/3 at 2 months + 1/3 at 3 months. Nair (1982) also found that potash application as 3 splits (1/3 as basal + 1/3 at 2 months + 1/3 at 3 months) was better for higher yield and starch content. Asokan and Sreedharan (1977) also were of the opinion that application of potassium as three splits at monthly intervals upto 3rd month was more effective. The beneficial effect of split application of potassium in increasing tuber starch content has also been reported by CIAT (1979). In the present study also maximum starch content is recorded by potash application for 0-4½ months. The slight reduction is starch content in prolonged K-application above 4½ months may be due to chloride injury (Reichard, 1964) or chloride induced sulphur deficiency (Howeler and Spain, 1980). There is no significant difference between the varieties H-2304 and M-4 so far as starch content is concerned.

14. Reducing sugar

The reducing sugar contents as influenced by different durations of potash application in the sand culture experiment is presented in table 20. The treatment which received potash from 0-4½ months records maximum reducing sugar content which is significantly superior to other treatments. The treatment with zero potash (T_1) records minimum reducing sugar content. The other treatments come in between these two treatments. The advantageous influence of split application of potash on starch content has been reported by Asokan and Sreedharan (1977), CIAT (1979) and Nair (1982). Being a carbohydrate, the same may be true for reducing sugar also. Gohock (1955) reported a marked rise of reducing sugar in storage organs of plants with adequate supply of potash. This explains the present finding.

15. Amylose content of starch

Table 21 presents data on the amylose content of starch under different durations of potash nutrition in the sand culture experiment. Application of potash for 0-4½ months (T_4) records maximum amylose content, which is significantly superior to all other treatments. The minimum amylose content is recorded by treatment receiving zero potash. The effect of potassium on quality has been reported by several workers like Kumar et al. (1971), Asokan and Sreedharan (1977) and Nair (1982). Moorthy and Naini (1980) found that tubers with better cooking qualities contained higher amounts of amylose. According to them, when potash is supplied adequately the cooking quality improves and amylose content of starch also increases. The amylose content of variety M-4 is significantly higher than variety H-2304 which may be varietal character.

16. Granule size of starch

From table 22 it can be seen that there is variation in the granule size of the starch under different durations of potash nutrition in the sand culture experiment. The treatment T_4, which received potash nutrition for 0-4½ months records maximum granule size which is significantly superior to other treatments. The treatment with zero potash and potash nutrition for 0-1½ months (T_1) record minimum granule size which are not significantly different from each other. According to Rosenthal (1970) the granule size of cassava starch varied from 5-26 µ. Moorthy and Maini (1980) also found that there are variations in granule size of cassava starch. Potassium increased the granule size of cassava starch (IITA, 1981). This may be due to a higher turgor pressure exerted by higher K-content inside the cells. Between the varieties M-4 is significantly superior to H-2304 as far as granule size is concerned.

17. Alkali number of cassava starch

Alkali number is one of the factors for evaluating the quality of starch. Table 23 presents the alkali number of starch under different durations of potash nutrition in the sand culture experiment. The maximum alkali number is recorded by treatment T_4, receiving potash nutrition for

0-4½ months and the minimum by zero potash (T_1). Other treatments come in between these two values. There is little work on the effect of potash nutrition on alkali number of cassava starch. Moorthy and Maini (1980) studying the properties of cassava starch did not get any relationship between alkali number and cooking quality of tuber. In this study variety M-4 records significantly higher alkali number than variety H-2304. M-4, being a variety with good cooking quality shows that higher alkali number may be accompanied by good cooking quality.

18. Pasting temperature of starch

Table 24 presents data on the pasting temperature of starch under different durations of potassium nutrition. Application of potassium for 0-4½ months (T_4) records maximum pasting temperature and it is significantly higher than all other treatments. Zero potash (T_1) records minimum pasting temperature. Pasting temperature is considered as one of the parameters for cooking quality of starch. The effect of potash nutrition on this factor has not been studied yet. Moorthy and Maini (1980) studying the properties of cassava starch (from different cultivars) found that pasting temperature was positively correlated with cooking quality. Variety M-4, which is well known for its good cooking quality is significantly higher than variety H-2304 as far as pasting temperature is concerned.

19. Viscosity of starch

Table 25 presents data on the viscosity of starch under different durations of potash nutrition in the sand culture experiment. Treatment T_4, which received potash nutrition for 0-4½ months, records maximum viscosity, but is not significantly different from treatments receiving potassium for 0-3 months (T_3) and for 0-10 months (T_5). The lowest viscosity is shown by zero potash (T_1) and potash nutrition for 1½-4½ months (T_9). In this study there is no significant relationship of viscosity with cooking quality or potash nutrition. Moorthy and Maini (1980) also did not get any relationship of viscosity with cooking quality.

20. Swelling volume of starch

The data on swelling volume of starch under different durations of potash application in the sand culture experiment is presented in table 26. From the results, it can be seen that for the treatments where the duration of potash nutrition was for 0-4½ months (T_4), 0-3 months (T_3) and 0-10 months (T_5) are on par though the first treatment (T_4) records highest swelling volume. Potash nutrition for 1½-3 months (T_8), 1½-4½ months (T_9) and zero potash (T_1) are in descending order and are not significantly different.

According to IITA (1981) potassium increases the size of storage cells in cassava tubers. Hence this may be the reason for the higher swelling volume of cassava starch in potassium treated plots. Adequate requirement of potassium may lead to higher swelling volume of starch. The treatment with zero potassium records minimum swelling volume. This again proves the effect of potassium on the increase of size in storage cells viz., starch granules.

21. Reducing value of starch

Table 27 presents data on the reducing value of starch under various durations of potash nutrition in the sand culture experiment. The treatment receiving potassium nutrition for 0-4½ months (T_4) records maximum and zero potassium (T_1) records minimum reducing value. The other treatment come in between these two values. Since potassium nutrition for 0-4½ months gives tubers of good cooking quality this factor may be a indicator of the same. Not much work has been done on the effect of potassium on reducing value of starch. Moorthy and Maini (1980) are of the opinion that reducing value does not seem to have much influence on the quality of starch.

22. Hydrocyanic acid content of tubers

Table 28 presents data on the variation of hydrocyanic acid in tubers as influenced by different durations of potash application. The HCN content is maximum in treatment receiving zero potassium (T_1), which is significantly different from other treatments. The minimum HCN content is recorded by treatment T_4 which received potassium nutrition for 0-4½ months. Other treatments come in between. The effect of K-nutrition on the reduction of HCN content in cassava has been reported by many workers like Obigbesan (1973), Pushpadas and Aiyer (1976), Asokan and Sreedharan (1977), Nair et al. (1980), Muthuswamy and Chiranjivi Rao (1981) and Nair (1982). According to Nestel and Mac In Tyre (1973) the elevated cyanogenic glucosides are a result of large non-protein nitrogen pool resulting from a deficiency of macro or micro-nutrients. Hence inadequate supply of potassium may result in elevated cyanoglucosides viz., HCN contents in the present study.

FIELD (MONO PLOT) EXPERIMENT

1. Yield of tuber

The yield of tubers under various levels of potash nutrition in the field experiment is presented in table 29 and Fig.4. From the table it can be seen that potassium @ 100 kg K_2O/ha (T_3) records maximum yield which is significantly superior to all other treatments. Grossman and Aosla (1951) got response of cassava for 100 kg K_2O/h sandy soils of Portugal. Chew (1970 and 1971) found 110-160 kg K_2O/ha was the requirement of cassava in p soils of Malaysia. From annual reports of CTCRI (1970, 71, 72 and 73) it can be seen that cassava responded to 100 kg K_2O/ha in laterite soils. Samuels (1970) got response of cassava to 100 kg K_2O/ha in Puetro Rica. Ngongi et al. (1977) reported that K_2O @ 120 kg/ha was adequate for cassava in Colombia. Rajendran et al. (1976) got response for 100 kg K_2O/ha in laterite soils of Trivandrum. Kumar et al. (1971) from experiments in laterite soils of Trivandrum concluded that the yield of cassava increased upto 105 kg K_2O/ha. Kanapathy (1970) found that in Kuala Lumpur the optimum dose of potash for cassava was 100 kg K_2O/ha. Asokan and Sreedharan (1977) from field experiments at Vellayani reported that maximum yield was obtained at 135 kg K_2O/ha for var. H-97. Pushpadas and Aiyer (1976) reported highest yield of cassava var. H-105 at 125 kg

K_2O/ha at Vellayani. Sheela (1981) also got response for 135 kg K_2O/ha at Vellayani for cassava. Nair (1982) got highest yield at 125 kg K_2O/ha for var. H-2304 at Vellayani. In the present study zero potash (T_1) records minimum yield which is significantly inferior to all treatments. According to Beringer (1978) more than 60 enzymes are known to need K as an activator, including starch synthetase. Thus potassium plays a major role in starch synthesis and translocation. Considering the importance of potassium on starch synthesis this result is biochemically and physiologically justifiable. At a level above 100 kg K_2O/ha, slight reduction in yield has been observed in the present study. Similar results were obtained by Reichard (1964), Rajendran *et al.* (1970), Nair and Kumar (1980) and Nair (1982). According to Ngongi *et al.* (1977) and Howeler and Spain (1980) this reduction of yield at higher levels of KCl can be partly attributed to chloride induced sulphur deficiency. They had observed in one of their studies that deficiency of sulphur can be prevented when KCl was mixed with elemental sulphur in the same proportion as they occur in K_2SO_4. Treatments with K_2SO_4 or KCl + S remained healthy while treatment with KCl alone showed sulphur deficiency at higher levels.

The beneficial effect of K nutrition in enhancing tuber yield of cassava was reported by several workers such as Kumar and Nair (1969), Pushpadas and Aiyer (1976), Asokan and Sreedharan (1977), Pillai and George (1978), Nair et al. (1980) and Nair (1982). Among the two varieties, H-2304 is significantly better yielder than M-4. Similar results were obtained by Nair (1982). It is evident that it is a varietal characteristic.

2. Number of tubers

Table 30 presents data on the number of tubers per plant. Potash application @ 100 kg K_2O/ha (T_3) records maximum number of tubers per plant. Levels of potash above this do not significantly enhance the number of tubers. Nair (1982) also reported a similar increase in tuber numbers upto 250 kg K_2O/ha. For efficient photosynthesis by leaves an adequate supply of potassium is essential (Russel, 1973). Pushpadas and Aiyar (1976) found increase in number of tubers at higher rates of potassium in cassava varieties H-105 and M-4. Mandal and Mohan Kumar (1972) also obtained similar increase in cassava variety H-165. Magoon et al. (1972) found that tuber number per plant significantly and positively correlated with tuber yield.

3. Length and girth of tubers

Tables 31 and 32 present data on the mean length and girth of tubers under various levels of potassium. It can be seen that the length of tuber and girth of tuber generally increase as the level of potassium increase. In the case of length of tuber, it is maximum in plots receiving potash @ 150 kg K_2O/ha (T_4) but is not significantly different from 200 kg K_2O/ha (T_5) Magoon et al. (1972) found that there is a positive correlation between length and girth of tuber on one side and yield on the other in cassava. The length and girth of tuber are minimum in zero potash (control) plots (T_1). Abraham and Nair (1980) reported significant association of tuber length with yield in *Dioscorea* spp. Thamburaj and Muthukrishnan (1976) also reported the positive association of tuber girth in the tuber yield in sweet potato. Variety H-2304 is significantly superior to M-4 as far as length and girth of tuber are concerned. This may be due to varietal character. Nair (1982) also reported similar results.

4. Height of plant

The mean height of plants due to various levels of potash application in the field experiment is presented in table 33. As the level of potash increase the height of plant also increase. Maximum plant height is recorded by 150 kg K_2O/ha. Nair (1982) also reported maximum plant height at 125 kg K_2O/ha in cassava. Similar results have been reported by Ngongi (1976) and Asokan and Sreedharan (1980) in cassava. Zero potash (T_1) records minimum height. Mean height of variety M-4 is significantly higher than variety H-2304. This may be due to the fact that M-4 is having a non-branching erect plant type.

5. Girth of stem

Table 34 presents data on the average girth of stem under various levels of potash nutrition in the field experiment. Eventhough potash application @ 200 kg K_2O/ha (T_5) records maximum girth of stem, it is not significantly different from potash @ 150 kg K_2O/ha. Zero potash (T_1) recorded minimum stem girth and other treatments come intermediary. Ramanujam and Indira (1980) found that there was no significant relationship between stem girth and yield, but higher stem girth was effective in increasing total dry weight. Nair (1982) also reported that potassium levels showed significant effect in top yield. Asher *et al.* (1980) reported that potash deficiency was characterised by thin stems in cassava.

6. Length of petiole

Table 35 presents data on the length of petiole under different levels of potash nutrition. Potash @ 200 kg K_2O/ha (T_5) records maximum length of petiole eventhough it is not significantly different from potassium @ 150 kg K_2O/ha (T_4). As the levels of potassium decrease the length of petiole also decrease and minimum length of petiole is recorded by zero potassium (T_1). Bussler (1964) reported that K-deficiency restricted the growth of all plant organs. Asher and Edwards (1980) also reported short petioles as a symptom of potassium deficiency in cassava. Variety H-2304 is significantly superior to variety M-4 as far as length of petiole is concerned which may be a varietal character.

7. Total number of leaves produced

Table 36 presents data on the variation of total number of leaves produced by cassava throughout the growth period, due to different levels potash application in the field experiment. It can be seen that potash application @ 50 kg K_2O/ha (T_2) records maximum number of leaves. But it is not significantly different from potash @ 100 kg K_2O/ha (T_3). Again potash @ 150 kg K_2O/ha (T_4) and 200 kg K_2O/ha (T_5) are not significantly different from each other and are at par with zero potash (Control). This clearly shows that potassium application has not much influence on the vegetative growth of cassava. Nair (1982) also reported the lesser influence of potassium on vegetative growth.

8. Number of leaves retained

Table 37 presents data on the number of leaves retained, expressed as per cent of total leaves. Treatment T_3 in which received potash @ 100 kg K_2O/ha records maximum leaf retention capacity, but it is not significantly different from potassium application @ 150 kg K_2O/ha (T_4) and 200 kg K_2O/ha (T_5). Zero potash (T_1) records minimum number of leaves retained. Edwards (1982) reported that potassium fertilisation increased tolerance to water stress in plants. This may be the reason for the high leaf retention capacity of cassava plants at higher levels of potassium.

9. Number of leaves shed

The number of leaves shed during the growth period of cassava crop under different levels of potassium in the field experiment expressed as per cent of total leaves is presented in table 38. Minimum leaf fall is recorded by potassium application @ 200 kg K_2O/ha. But it is not significantly different from potash @ 150 kg K_2O/ha. As the levels of potash increase, the leaf fall rate decreases. Maximum leaf fall is recorded by zero potash (T_1). According to Edwards (1982) potash fertilization increased tolerance to stress in plants. This explains the minimum number of leaf fall in plants receiving high rates of potassium application.

10. Dry matter content of tuber (flesh)

Table 39 presents data on the dry matter content of tuber under different levels of potassium in the field experiment. The level of potash @ 100 kg K_2O/ha (T_3) records maximum dry matter content of tuber which is significantly superior to all other treatments. Potassium @ 150 kg K_2O/ha (T_4) and 200 kg K_2O/ha (T_5) record still lower dry matter contents of tuber and are in the descending order. Zero level of potassium (T_1) records minimum per cent of dry matter in the tuber. The dry matter content of tuber increases as the levels of potash increase upto 100 kg K_2O/ha. Above this level there is a slight reduction. Pushpadas and Iyer (1976), Pillai (1967), Asokan and Sreedharan (1977) and Nair (1982) found that potassium application increased the dry matter content of cassava tubers.

11. Dry matter content of rind

Table 40 presents data on the dry matter content of rind under different levels of potash in the field experiment. The potash level @ 100 kg K_2O/ha (T_3) records maximum dry matter content of rind which is significantly superior to all other treatments. There is a slight reduction in the dry matter per cent of rind above this level. Zero potash (T_1) records minimum dry matter content of rind. Magoon *et al.* (1972) found that there is a positive correlation between yield characters like tuber length, plant height and rind thickness in cassava. Among the varieties H-2304 is having significantly more dry matter in rind than variety M-4. It may be possible that when the tuber flesh contains more dry matter the tuber rind also may contain more dry matter. Naini and Balagopal (1978) also found that there is a positive correlation between dry matter per cent of flesh and rind in cassava tuber.

12. Rind content of tubers

Table 41 presents data on the rind content of tubers at different levels of potassium in the field experiment. Eventhough the level of potash @ 200 kg/ha records minimum rind per cent it is not significantly different from other treatments. But as the level of potash increase there is a decrease in the rind per cent. Thus zero potash records minimum rind per cent. As there is no significant difference between treatments, this character is not much influenced by potash nutrition.

13. Fibre content of tubers

The fibre content of tubers under different levels of potassium in the field experiment is presented in table 42. Zero potash (T_1) records maximum fibre content which is significantly higher than all other treatments. As the level of potash increases the fibre content decreases. Potash level @ 250 kg K_2O/ha records minimum fibre content. Thus there is a negative correlation between level of potash and fibre content of tuber. Muthuswamy and Chiranjivi Rao (1981) reported that potash application decreased the fibre content with maturity of cassava tubers. Variety H-2304 records significantly more fibre content than variety M-4 which may be a varietal character.

14. Starch content of tubers

The variation of starch content in tubers at different levels of potassium in the field experiment is presented in table 43. The level of potash @ 100 kg K_2O/ha (T_3) records maximum starch content, but is not significantly different from potash @ 200 kg K_2O/ha significantly different from potash @ 200 kg K_2O/ha (T_5) and 150 kg K_2O/ha (T_4) which follow in descending order. Zero potash records minimum starch content. The starch content is generally increasing as the levels of potassium increase. The effect of potassium in increasing the starch content of cassava tubers was recognised by Blin (1905). Many workers like Black and Cairns (1955), Lachover and Arnon (1962), Pillai (1967), Kumar *et al.* (1971), Obigbesan (1973), Pushpadas and Aiyer (1976), Rajendran et al. (1976), Asokan and Sreedharan (1977), Pillai and George (1978), Gomes *et al.* (1980), Nair *et al.* (1980) and Nair (1982), reported that potassium application increased the starch content of cassava tubers.

In the present study the starch content is significantly increasing only upto 100 kg K_2O/ha. Thereafter there is a slight reduction in the starch content of tubers. The same results were obtained by Kumar *et al.* (1971) and Nair *et al.* (1980). Nair (1982) found that the starch content of cassava tubers (var. H-2304) increased upto 200 kg K_2O/ha. CIAT (1979) reported linear increase in starch yield with potash application only upto 200 kg K_2O/ha. The observation in the present investigation is in confirmity with the above findings that after a certain level the starch content decreases.

Reichard (1964) and Ugongi *et al.* (1977) reported that higher levels of KCl depressed yields due to chloride injury. This may be the reason for the decrease in starch content also at higher levels of muriate of potash. In the present study KCl is used as the source of potassium since it is the only potassic fertilizer available in the market and is being used by all farmers.

The beneficial effect of potassium on starch content can be explained by the role of potassium in synthesis and translocation of carbohydrates. Scheck (1953) reported that plants fertilised with potash can produce more carbohydrates by photosynthesis during day. A positive correlation between potassium and starch content in potato was reported by Coves and Loofe (1953), Black and Cairns (1958), Ward (1959) and Sukla and Singh (1976). According to Davidescu and Davidescu (1981) a lack of K blocks many fundamental enzyme reactions, whilst its presence intensifies the activity of the same.

Tugise and Tanno (1967) reported the beneficial effect of potassium on the starch content of sweet potato tubers. Rai *et al*. (1980) reported that potassium @ 120 kg K_2O/ha increased the yield of sweet potato. According to them the effect of potassium may be due to its capacity for increasing the mass of parenchymatous cells which contain starch grains as the multiplication of tertiary cambium.

In the present study variety H-2304 is significantly superior to variety H-4 as far as starch content is concerned. This may be a varietal character.

15. Reducing sugar content

Table 44 presents data on the reducing sugar content of tubers under different levels of potassium in the field experiment. Eventhough potash @ 100 kg K_2O/ha (T_3) records maximum reducing sugar, it is not significantly different from potash @ 150 kg K_2O/ha (T_4) and 200 kg K_2O/ha (T_5) which are in the descending order. Zero potash (T_1) records minimum reducing sugar and is significantly lower than all other treatments. Bo (1959) got positive response of carbohydrate content in potato and K application. Scheck (1953) reported that reducing sugar in storage organs of plants rise markedly with potash supply. Mengel (1975) showed that K favourably affected sugar synthesis and its translocation in plants. Kanwar (1973) reported that K-deficiency resulted in a decrease in reducing sugar. This may be the reason for high sugar content when the level of potassium increased. Variety H-2304 and M-4 are not significantly different as far as reducing sugar is concerned.

16. Amylose content of starch

Table 45 presents data on the variation of amylose content of starch in tubers at different levels of potassium in the field experiment. Though potassium @ 200 kg K_2O/ha (T_5) records maximum amylose content it is not significantly different from potash @ 150 kg K_2O/ha (T_4) and 100 kg K_2O/ha (T_3) which are in descending order. Generally the amylose content increases as the levels of potash increase. It is significant that increased amylose content leads to decreased amylopectin content since the granules of starch are well formed. In view of this both the industrial and cooking quality of starch improved with enhanced K nutrition. Studying the varietal differences on the properties of cassava starch from different varieties, Moorthy and Maini (1980) reported that amylose content is one of the most important factor having positive correlation with cooking quality. In the present study also, variety M-4 which is reputed for good cooking quality, records significantly higher amylose content than variety H-2304. It is significant that except for the present study there has been very little work on the relationship between the level of K nutrition in cassava and amylose content of tubers. Moorthy and Maini (1980) also found that variety M-4 is in higher amylose content group which possess better cooking quality.

17. Granule size of starch

The granule size of starch under different levels of potash in the field experiment is presented in table 46. It can be seen that potassium @ 200 kg K_2O/ha (T_5) records maximum granule size. But it is not significantly different from potash @ 150 kg K_2O/ha (T_4) and 100 kg K_2O/ha (T_3) which are in descending order. Zero potash (T_1) records minimum granule size of starch. Rosenthal (1970) examined some characteristics of cassava starches and found that the granule size varied from 18-25 μ. Moorthy and Maini (1980) studying the differences in the properties of cassava starch, found that the granule size differed considerably among the varieties and within the variety. Within the variety the variation in granule size may be due to nutrition. Dussler (1954) reported about the direct action of potassium in enzymatic reactions, because the protein component of the enzyme is always subject to the swelling effect produced by potassium. Lundegardh (1951) from his experiments concluded that the K-ion has a specific effect on protoplasm. Hetzner (1958) found that multivalent ions raise the consistency of the protoplasm. Potassium alone or in combination with N increased the number and size of storage cells in cassava tubers (IITA, 1981). There was a positive correlation between applied K and size of storage cell. This may be due to a higher turgor pressure exerted by higher K content inside developing cells.

18. <u>Alkali number of starch</u>

Table 47 shows the data on the variation of alkali number of starch under different levels of potassium in the field experiment. There is no significant difference between levels of potassium. This character does not seem to influence the quality of starch much. But variety M-4 is showing significantly higher reducing value than variety H-2304. This may be due to varietal character.

19. <u>Pasting temperature of starch</u>

The variation of pasting temperature of starch under different levels of potash in the field experiment is presented in table 48. Potash @ 200 kg K_2O/ha (T_5) records maximum pasting temperature and is significantly superior to other treatments. As the levels of potash decrease the pasting temperatures also decrease significantly. This character of starch has a significantly high correlation with the starch quality. According to Moorthy and Nair (1989) pasting temperature is one of the most important character contributing to cooking quality. Variety M-4 is having significantly higher pasting temperature than variety H-2304 which may be due to varietal character (M-4 being the best variety as far as cooking quality is concerned).

20. Viscosity of starch

Table 49 presents data on the variation in viscosity of starch under different levels of potash in the field experiment. Eventhough potash @ 200 kg K_2O/ha (T_5) records maximum viscosity it is not significantly different from potash @ 150 kg K_2O/ha (T_4). Generally there is a positive correlation between viscosity of starch and the levels of potash. Zero potash records the minimum viscosity. Nair et al. (1978) found that as the starch degrade, the viscosity decreases. Again Moorthy and Maini (1980) consider viscosity as one of the characters for good cooking quality. ISI (1960) specified starch of high viscosity for textile industry. Variety M-4 which is considered to have very good cooking quality, is significantly superior to H-2304 as far as viscosity is concerned.

21. Swelling volume of starch

High swelling volume is considered as a good character as far as cooking quality is concerned. Table 50 presents data on the variation in swelling volume of starch under different levels of potassium in the field experiment. The maximum swelling volume is recorded by potash @ 200 kg K_2O/ha

(T_5), eventhough it is not significantly different from potassium @ 150 kg K_2O/ha (T_4). Zero potash records minimum swelling volume which is significantly lower than all other treatments. This character of starch also is considered as an index of good cooking quality. Moorthy and Maini (1980) reported that swelling volume of starch has a positive relationship with starch of good cooking quality. The higher swelling volume with higher K application may be due to the effect of K in increasing the storage cells in cassava (IITA, 1981). M-4, the acclaimed variety for cooking quality, is significantly superior to variety H-2304 as far as swelling volume of starch is concerned. This may be due to varietal character.

22. Reducing value of starch

Table 51 shows the data on reducing value of starch under different levels of potash in the field experiment. Eventhough potash @ 150 kg K_2O/ha records maximum reducing value, it is not significantly different from potash @ 200 kg K_2O/ha. The minimum reducing value is shown by zero potash (T_1) and it is not significantly different from potash @ 50 kg K_2O/ha. Hence this character does not seem to have much influence on the quality of starch. Moorthy and Maini (1980) also are of the same opinion.

23. Hydrocyanic acid content of tubers

Table 52 presents data on the variation of HCN content of tubers under different levels of potassium in the field experiment zero potash (T_1) records maximum HCN content and as the levels of potash increase the HCN content gradually decreases. Bolhius (1954) found that K-deficiency increased the linamarin content of cassava tubers. The effect of potassium on the reduction of HCN content in cassava has been reported by many workers like Obigbesan (1973), Pushpadas and Aiyer (1976), Asokan and Sreedharan (1977), Nair *et al.* (1980), Muthuswamy and Chiranjivi Rao (1981) and Nair (1982). Nestel and Mac In Tyre (1973) reported that the elevated cyanoglucosides as a result of large non-protein nitrogen pool resulting from a deficiency of macro or micro nutrients, particularly in laterite soil. The increase in HCN content with decrease in potash levels may be attributed to the above reason. Between the varieties H-2304 is having significantly higher HCN content than variety M-4. This may be a varietal characteristic.

Path coefficient analysis for yield and yield components and starch and starch characters

1. Sand culture experiment

Among the various factors influencing yield, it is found that maximum direct effect in influencing the yield is possessed by the total number of leaves retained till harvest. Similar result was reported by Nair (1982) on the same variety viz., H-2304. Among the other factors such as total number of leaves produced and total number of leaves shed though found to have an effect resulting in the total photosynthate and high yield is found to be maximised by a higher leaf number effectively retained throughout the growing period. The total retained leaf number at the time of harvest which is a measure of a high fraction of the total leaf area available for photosynthesis is evidently influencing both the number of tubers per plant and length and girth of the tuber. Thus the total yield increase is found to be influenced through increased tuber number and tuber length. Height of plant and girth of stem are evidently interlinked factors which decide total number of leaves retained. Edwards (1982) reported that the effect of N-nutrition on leaf retention capacity may be due to its influence on increased tolerance to water stress. Thus a greater number of leaves leads to more photosynthesis and hence the increase in yield. Thamburaj (1976) and Lakshmi and Easwari Amma (1980) reported positive relationship of number of leaves and tuber yield in sweet potato and Dioscorea respectively. Magoon et al. (1972) found that there exists a positive correlation between tuber length and tuber girth on one side and yield of tubers on the other. IITA (1982) reported that the correlations between yield and the following yield components are highly significant: Number of tuber per plant, tuber size, stem girth and plant height.

As for the starch and starch characters maximum direct effect is due to amylose content. The significant correlation of other characters is due to their direct effect and indirect effect through amylose content. Moorthy and Maini (1980) reported that amylose content is one of the most important factor having positive correlation with cooking quality. In the present study also it is observed that the amylose content increases with increase in potash level and simultaneously cooking quality also improves.

2. Field (Microplot) Experiment

In the field experiment path coefficient analysis shows that the maximum direct effect is via dry matter content of rind. This is mainly due to the positive direct effect of the same and positive indirect effect via length of tuber and height of plant. Magoon et al. (1972) found that there is a positive correlation between yield characters like tuber length, plant height and dry matter content of rind. Height of plant is the most important factor influencing the yield. Nair (1982) also reported maximum plant height at a level of K, where maximum yield was obtained. Similar results have been reported by Ngongi (1976) and Asokan and Sreedharan (1980) in cassava. Starch and starch characters show that the positive direct effect on starch content is through amylose content which is in agreement with the result in the sand culture experiment. In the field experiment also as the starch content increases, the HCN content decreases. This is due to the effect of potassium in increasing the starch content and decreasing the HCN content. Similar results were reported by many workers like Pillai (1967), Kumar et al. (1971), Obigbesan (1973), Pushpadas and Aiyer (1976), Rajendran et al. (1976), Asokan and Sreedharan (1977), Gomes et al. (1980), Nair et al. (1980) and Nair (1982).

Soil characteristics and soil analysis

The soil of the experimental field was red loam (sandy loam as per textural classification) and was low in available nitrogen and medium in available phosphorus and potassium (refer table 61). The pH was acidic (5.35) and organic carbon and cation exchange capacity low. Similar results were reported by Natarajan (1975), Pillai (1969), Pushpadas and Aiyer (1976), Asokan and Sreedharan (1980) and Nair (1982). The soil available potassium after each crop during the exhaustion crops is presented in table 62. It can be noted that the mean initial soil available K of 150 kg K/ha decreased to 118.2 kg K/ha after the first crop and to 65.2 kg K/ha after the second. Even without addition of potash, the soil available K could be brought to only 1/2.3 of the original available K. Prabhakumari (1981) from soil exhaustion studies due to continuous cropping with cassava for two seasons found a decrease of about 1/3 of the total soil available K in the same soil viz., red loam. Table 63 presents data on the available K and total K status of the soil before and after the experiment with different levels of potash viz., 0, 50, 100, 150 and 200 kg K_2O/ha. It can be observed that even in zero potash treatment there is a residual effect of 98.5 kg/ha of available K. This shows that the unavailable forms of potash in the soil reserve is gradually released and become available. Rajendran et al. (1976) also reported that about 1 - 2 per cent of the total potassium in the soil will be converted to available K every year in laterite soil. Eventhough the release of fixed K to available form is governed by many factors like the type of clay mineral, parent material and weathering conditions, a portion of the total K will be released to available forms. The residual effect may be due to this released potassium from soil potassium reserve. This also accounts for the impossibility of completely exhausting the soil from potassium under field conditions.

Thus it appears that the available pool of soil potassium is continuously replenished from the non-exchangeable reserve, although the pattern of release in different soils is not uniform. It should be noted that while the soil test values pertain to plough layer, the subsoil contribution may be substantial. Whether a small amount of fertilizer K can mobilise a large proportion of native potassium in an intensive cropping system is worth investigating. The results, however, point out that the soils capacity to supply potassium to the plants is inexhaustible under field conditions since replenishment occurs from soil potassium reserves which is progressively built up through many natural sources like rainfall, plant residues etc.

Nutrient concentration in plant parts

1. Sand culture experiment

Potassium

The concentration of potassium in the leaf at 4th month and at the time of harvest (10th month) is presented in Table 64. It may be noted from the table that the concentration of potassium is higher at 4th month when compared to 10th month. Pushpadas and Aiyer (1973) reported that N, P and K in the petiole at 4½ months stage, was highest and correlated with the yield. Asher et al. (1980) found that nutrient concentrations of leaf samples (YFEL) taken at 3-4 months of age depicted the maximum concentrations in the plant, which was the best time for leaf sampling in cassava. CTCRI (1969) reported that the maximum per cent of potassium in all plant parts viz., leaf, stem and tuber was at 4th month stage when compared to 6th and 8th month. Again it can seen from the table that maximum per cent of potassium is recorded by the treatment where potassium is supplied from 0-10 months. This may be due to luxury consumption as reported by Rajendran et al. (1976).

The uptake of potassium by cassava at different durations of K-application is presented in Table 65. It may be noted that the uptake of K and yield are not correlated. The maximum uptake is for 0-10 months duration of K-application but the maximum yield is for 0-4½ months of potassium nutrition. This may be due to luxury consumption of potassium as reported by Rajendran et al. (1976). From the table it can be seen that the critical period of potassium nutrition is 0-4½ months. Asokan and Sreedharan (1978), CIAT (1979), Nair (1982) and Asokan and Vikraman (1983) have also reported the beneficial effect of potassium application as three splits viz., 1/3 as basal + 1/3 at 60 days after planting + 1/3 at 90 days after planting. The maximum concentration of potassium in the leaf is found at 3-4 month stage of the plant as reported by CTCRI (1969) and Asher et al. (1980). Hence the application of potassium at 4½ months stage can be fully justified from the approach of the above mentioned authors and the results of the present study. The best yields under sand culture have been obtained for K nutrition from 0 to 4½ months period.

Nitrogen and phosphorus

The uptake of nitrogen and phosphorus by cassava at different durations of potassium application is presented in table 66. As far as nitrogen is concerned, its uptake is not correlated with the uptake of potash. The treatment which received potassium nutrition for 0 to 4½ months records maximum nitrogen uptake as well as maximum yield. There is no correlation between the uptake of potassium and that of nitrogen. This may be due to the fact that there is no luxury consumption in the case of nitrogen. Nair (1982) has also reported that there is no correlation between N and K uptake. The uptake of nitrogen is minimum in zero potash application. This shows that eventhough there is no significant correlation between the uptake of N and K, there is a particular relationship between the level of potassium application and nitrogen uptake. This reduction in the uptake of N when K is limiting may be due to the fact that the N:K ratio is disturbed in this treatment. The optimum N:K ratio for cassava has been reported as 1:1 by Coura (1953), Kumar *et al.* (1971) and Rajendran *et al.* (1976). A ratio of 1:1.2 has been reported by Rodriguez (1975) and Asokan and Sreedharan (1977). Nair (1982) found that potassium upto 125 kg K_2O/ha influenced the nitrogen uptake. In any case the non-maintenance of this particular N:K ratio may be the reason for the low uptake of N at zero potash. Generally the nitrogen uptake of H-2304 is greater than M-4. This may be a varietal character since H-2304 is a high yielder comparatively.

The phosphorus uptake is not much influenced by the duration of potassium application. Generally the uptake of P by H-2304 is greater than M-4, which can be attributed to varietal character.

The ranges of uptake of N, P and K are 76.48 - 150.61, 21.13 - 29.61 and 15.55 - 301.59 kg/ha respectively. The maximum variation is for potassium which can be attributed to luxury consumption. The minimum variation is for phosphorus which is needed only in small amounts when compared to N and K. These results are in conformity with the results obtained by Greenstreet and Lambourne (1933), Potaschenko (1961), Cours and Fritz (1961), Ponnaiyathy (1970), Pushpadas and Aiyer (1976), Asokan and Sreedharan (1977), CTCRI (1978) and Nair (1982).

Concentration of N, P and K and distribution of fresh and dry matter in plant parts

The average concentration of N, P and K in different plant parts viz., leaf, petiole, stem and tuber are presented in table 67. It can be observed from the table that the maximum per cent of nitrogen is in the leaf and in the descending order in petiole, stem and tuber. Phosphorus also is highest in the leaf and the next part in descending order is the stem, followed by petiole and tuber. But in the case of potassium maximum per cent of this element is found in the petiole, followed by leaf, stem and tuber in descending order. These results are in agreement with the findings of Rajendran et al. (1976), Pushpadas and Aiyer (1976), Howeler (1978) and Nair and Kumar (1980). The fresh matter and dry matter per cent in different plant parts are also shown in table 67. It is seen that maximum fresh matter and dry matter per cent is in the tuber, followed by stem, leaf and petiole. This result is in agreement with that of Howeler (1978) and Nair (1982).

Potassium deficiency

Deficiency of potassium was characterised mainly by a severe reduction in plant height and girth and short petioles and small leaves. This is in agreement with the finding of Lozano *et al.* (1976) and Asher (1980). In early stages viz., at 4th week small purple spots appeared on older leaves and curling of leaf margins appeared. Krochmal and Samuels (1968) and Asher *et al.* (1980) have also reported the same symptoms of potassium deficiency in the early stages of the plants growth. As the deficiency intensified, chlorosis developed at the tips and along the margins of the leaves and border necrosis was found. Asher *et al.* (1980) also described the same symptoms of potassium deficiency in cassava. There was a brown discoloration of the petiole which was again reported by Spear *et al.* (1978) and Asher *et al.* (1980). In potassium deficient plants the concentration of this element in the YFEL is found to be 0.38 - 0.50 per cent (table 68). This is in agreement with the results obtained by Howeler (1978) and Asher *et al.* (1980).

2. Field experiment

The concentration of potassium in the leaf at 4th month and at 10th month stages is presented in table 69. Eventhough between the varieties there is no significant variation, as the level of K_2O increases, the per cent of potassium in the leaf also increases. Generally the potassium concentration in the leaf is higher at 4th month stage. Similar results of maximum concentration in leaf potassium at 3 to 4 month stage in cassava were reported by CIAT (1969) and Asher et al. (1980). Rajendran et al. (1976) found that at harvest the K_2O per cent in tuber, leaf and stem increased as the levels of potassium increased from 0 to 150 kg K_2O/ha. Nair and Kumar (1980) also reported that the K-concentration in the leaf of cassava correlated positively with the levels of potassium application. The range of potassium concentration viz., 0.90 - 2.36 per cent found in the present study agrees with the results of Rajendran et al. (1976), Asher et al. (1980) and Nair and Kumar (1980). The relationship between yield and concentration of potassium in the leaf is shown in Fig.8. It may be seen from the figure that the yield increases only upto 100 kg K_2O/ha, while the concentration of potassium increases upto the highest level viz., 200 kg K_2O/ha. This clearly shows the luxury consumption of potassium by cassava. Rajendran et al. (1976) and Nair and Kumar (1980) have also reported the same results about the luxury consumption of potassium. Howeler and Spain (1980) found that at higher levels of KCl the yield of cassava was reduced due to chloride induced S-deficiency. This may be the reason for the reduction of yield at higher levels of KCl.

The critical value of potassium in the leaf (YFEL) blade is K = 1.866 per cent (for var. H-2304) and K =1.834 per cent (for var. M-4) at 4th month stage. Prevot and Ollagnier (1950) showed that the critical level of K in cassava leaf was 1.2 per cent. Spear et al. (1970) found a critical value of 1.1 per cent for potassium in cassava leaf (YFEL). CIAT (1981) reported a critical value of 1.5 per cent for (YFEL). YFEL blades of 3 - 5 months. It can be observed from the available data that the critical concentration of potassium in the leaf varies with variety. This may be the reason for the small differences in the critical value obtained by different workers.

The relationship between the tuber yield and levels of potassium is shown in Fig.7. From the figure, it can be noted that the tuber yield increases upto 100 kg K_2O/ha and above this level, the yield gradually declines. Response curves were fitted and the response of potassium level for highest yield is found to be 129.44 kg K_2O/ha for variety H-2304 and 126.66 kg K_2O/ha for variety M-4. Taking the price of cassava and potash into consideration the most economic level is found to be 102.02 kg K_2O/ha for variety H-2304 and 104.19 kg K_2O/ha for variety M-4. Kumar *et al.* (1977) reported that the optimum level of potassium for cassava (variety H-97) was 105.9 kg K_2O/ha in laterite soil. Asokan and Sreedharan (1977) showed that the maximum tuber yield for cassava (variety H-97) was obtained at 135 kg K_2O/ha in red loam soil. Nair (1982) found that 125 kg K_2O/ha gave maximum net profit for cassava (variety H-2304) in red loam soil. These results are in agreement with the present finding.

The uptake of potassium by cassava at different levels of potassium is presented in table 70. From the table, it can be seen that a positive relationship exists between the levels of potassium and its uptake by cassava. But from figure 4, it may be noted that above a level of 100 kg K_2O/ha there is no yield increase. This clearly shows that there is luxury consumption of potassium as reported by Rajendran *et al.* (1976). Above 100 kg K_2O/ha, there is a slight reduction in yield, which is due to chloride injury as reported by Richard (1954) or chloride induced sulphur deficiency as reported by Howeler and Spain (1980). The uptake of potassium corresponding to the maximum yield is 149.67 kg/ha. Similar results were obtained by Kanapathy (1974), Rajendran *et al.* (1976), Nair and Kumar (1980) and Nair (1982).

The concentration of potassium in different plant parts viz., leaf, petiole, stem and tuber and the dry matter content of tuber at different levels of potassium are presented in table 71. It can be seen that the maximum per cent of K is in the petiole followed by leaf, stem and tuber in descending order. This result is in agreement with the observations of Rajendran *et al.* (1976), Pushpadas and Aiyer (1976), Howeler (1970) and Nair and Kumar (1980).

The uptake of N and P at different levels of K-application is shown in table 72. It can be noted that eventhough the uptake of N is not significant it increases with higher levels of K. There is no relationship between the uptake of P and levels of K application. Similar results were obtained by Nair (1982). The relationship between N and K uptake may be due to the fixed N:K ratio in cassava. An optimum N:K ratio of 1:1 has been reported by Coure (1953), Kumar *et al.* (1971) and Rajendran *et al.* (1976). A ratio of 1:1.2 has been reported by Rodrigues (1975) and Asokan and Sreedharan (1977).

The effect of various levels of potassium on the utilization index is shown in table 73. It can be seen that the utilization index increases with the increase in the level of potassium eventhough it is not significant. But at the highest level of potassium application the utilization index is also maximum. Nair (1982) also reported maximum utilization index at highest level of potassium in red loam soil for variety H-2304, eventhough the increase was not significant. This insignificant increase in utilization index may be due to the fact that the increase in tuber yield by the application of potassium was accompanied by a corresponding increase in top yield.

Potassium nutrition and spider mite (*Eutetranychus orientalis* Klein) infestation in cassava

The extent of spider mite infestation in the field experiment for different levels of potassium at the time of harvest is presented in table 74. The accumulation of a large number of mites occur during summer months. According to CTCRI (1980) the population of mite is maximum from February-April which coincides with the harvest of the crop in March-April. From the table it can be seen that mite infestation is more in variety M-4 when compared to variety H-2304. This may be due to varietal difference in the resistance to pests. The treatments are significantly different upto 100 kg K_2O/ha. Generally as the levels of potassium increase, the per cent of mite infested leaves decreases (from 52.75% in K_0 to 23.72% in K_{200}). Chaboussou (1972) reported that potassium fertilization controls scale insects like mites. He found that foliar sprays of potassium nitrate was effective in controlling the mites. Raghunath (1939) also found that the incidence of scale insects was reduced considerably due to enhanced potash application. According to Chaboussou (1972) the possible reason for the reduction in scale insects like spider mites, may be due to the favouring of proteogenesis, which occurs with the establishment of a new substance between K^+ and Ca^{++}. This leads in the end to a lowering of the reducing sugar content and that of other soluble substances in leaf tissues. In this manner a condition unfavourable for the multiplication of spider mites is created. Another reason for the reduction in spider mites may be due to the function of potassium in the protection of plants from loss of water (Russler, 1964). Nelson (1978) reported that adequate K supply has an important role in the resistance or tolerance of moisture in the plant. According to CTCRI (1980) the mite infestation is more in the months of February-April when mean day temperature is maximum and relative humidity low. Under such circumstances the function of potassium in moisture conservation may reduce the mite infestation.

Cooking quality of tubers

The mean scores obtained by the two varieties viz., H-2304 and M-4 at different levels of potassium in the organoleptic test are shown in table 75. It can be noted that for variety M-4, which is acclaimed for best cooking quality is getting a high score even for zero potash treatment. This may be due to the varietal character. There is significant difference between the varieties and variety M-4 is significantly superior to variety H-2304.

As the level of potassium increase the cooking quality also improves. The influence of potassium on starch and HCN (Fig.5) show that as the level of potassium increases, the starch content increases and the HCN content decreases in the tuber. This may be the possible reason for the improvement in the cooking quality as the level of potassium increase. Asokan and Sreedharan (1977) and Nair (1982) also reported improvement of cooking quality of tuber with increased potassium application.

Critical discussion of the results

From the sand culture experiment on different durations of potassium application to cassava it is seen that maximum yield is obtained for the treatment receiving potassium from the time of planting to 4½ months growth (table 9 and fig.3). CTCRI (1969) reported that the maximum uptake of potassium by cassava is in the 4th month and that the zero potassium recorded lowest yield. In the present study also zero potassium recorded minimum yield. Asokan and Sreedharan (1977, 1978 and 1980) recorded highest yield when potassium was applied 1/3 as basal + 1/3 at 2 months + 1/3 at 3 months for cassava var. M-97. Similar results were reported by Natarajan (1979), Sheela (1981), Nair (1982) and Asokan and Vikraman (1983). Malvolta et al. (1955) found that when K was omitted from nutrient solution the yield of tubers in cassava decreased considerably. Similar observations had been made in the present study also (table 4). The number of tubers per plant, length and girth of tubers, height of plant, girth of stem, length of petiole, total number of leaves produced and number of leaves retained at the time of harvest, dry matter content of flesh and rind in tuber and starch and sugar content in tuber are maximum in 0-4½ months duration of potassium application. Pushpadas and Aiyer (1976) reported increase in tuber number at higher levels of potassium. Magoon et al. (1972) found that there was positive correlation between the height of plant and length and girth of tuber on one side and tuber yield on the other.

Asher *et al*. (1980) observed that in potassium deficient cassava plants there is a severe reduction in petiole length. Lakshmi and Easwari Amma (1980) found a positive significant association of number of leaves and tuber yield in Dioscorea. Thamburaj and Shanmugavelu (1980) reported the dry matter content of flesh was higher in cassava with higher yield.

The hydrocyanic acid and fibre contents of tubers are minimum (tables 18 & 20) and the starch content of tubers maximum (table 19 and fig.5) in 0-4½ months duration of potash application. Obigbesan (1973), Pushpadas and Aiyer (1976), Asokan and Sreedharan (1977), Nair *et al*. (1980), Muthuswamy and Chiranjivi Rao (1981) and Nair (1982) also reported reduction of HCN content and elevation of starch content in cassava tubers due to K-nutrition. Muthuswamy and Chiranjivi Rao (1981) found that the fibre content of tubers was decreased with maturity. The sugar content of tubers was highest in 0-4½ months duration of potash application (table 20). Scheck (1953) reported a marked rise of reducing sugar in storage organs of plants with adequate supply of potassium. The advantageous influence of split application of potash upto 90 days of growth in cassava on carbohydrate content has been reported by Asokan and Sreedharan (1977), CIAT (1979) and Nair (1982). Being a carbohydrate, the same may be true for reducing sugar also.

The amylose content, granule size, pasting temperature and swelling volume of starch are higher in tubers obtained from potassium application for 0-4½ months (tables 21, 22, 24 and 25). Moorthy and Maini (1980) found that cassava tubers with better cooking quality contained higher amounts of amylose. In the present study also it is observed that as the cooking quality improves, the amylose content also increases. According to IITA (1981) potassium increased the granule size of cassava starch. Such a significant observation has been made in the present study also (table 22). Moorthy and Maini (1980) studying the properties of cassava starch, found that pasting temperature was positively correlated with cooking quality. According to IITA (1981) potassium increases the size of storage cells in cassava tubers. In the present study also with adequate supply of potassium the swelling volume of starch increases.

The path coefficient analysis of yield and yield components show that maximum direct effect on yield is via number of leaves retained at the time of harvest (path diagram 3 and table 19). Edwards (1968) attributed this quality of potash application to prevention of water stress in plants. Lakshmi and Mecmari Amma (1980) and Nair (1982) have also observed significant association of number of leaves retained to yield in Dioscorea and cassava respectively. For the starch and starch characters maximum direct effect is due to amylose content. Moorthy and Maini (1980) found that tubers with better cooking quality contained more amounts of amylose. According to them when potash is supplied adequately the cooking quality improves and amylose content of starch also increases. In the present study also as the level of potash increased the cooking quality of tubers improved.

Potassium deficiency in zero potash treatment is characterised by a severe reduction in plant height, girth of stem, short petioles and small leaf blades (Plate 1). Border necrosis of older leaves and brown discoloration of petioles are other symptoms noticed.

From the field experiment with different levels of potash it is observed that 100 kg K_2O/ha significantly increases the yield (table 29 and fig.4). Grossman and Assis (1951), Samuels (1970), Kanapathy (1970), CTCRI (1970, 1971, 1972 and 1973) and Rajendran et al. (1976) reported maximum yield of cassava at 100 kg K_2O/ha. Pushpadas and Aiyer (1976) and Asokan and Sreedharan (1977) got maximum yield of cassava at 125 and 150 kg K_2O/ha respectively. Nair (1982) also reported highest yield at 125 kg K_2O/ha. In the present study the optimum level of potassium for cassava is found to be 128.03 kg K_2O/ha. At higher levels of KCl a slight reduction in yield is observed (Fig.4). Ngongi et al. (1977) and Fowler and Spain (1980) also reported reduction in yield of cassava at higher levels of KCl. Similar results were obtained by Reichard (1964), Rajendran et al. (1970), Nair and Kumar (1980) and Nair (1982). The number of tubers per plant, length and girth of tubers, height of plant, girth of stem, length of petiole, total number of leaves produced, number of leaves retained and dry matter content of flesh and rind in the tuber were higher at a potash level of 100 kg K_2O/ha (tables 30, 31, 32, 33, 34, 35, 36, 37, 39 and 40). Similar results were reported by Pillai (1967), Magoon et al. (1972), Thamburaj and Muthukrishnan (1976), Ngongi (1976), Nair and Balagopal (1978), Pushpadas and Aiyer (1976), Asokan and Sreedharan (1977 and 1980), Anber et al. (1980), Edwards (1982), Nair (1982) and IITA (1982). Maximum starch content of tubers is recorded by 100 kg K_2O/ha eventhough it is not significantly different from K_2O @ 150 and 200 kg/ha (table 43). The effect of potassium in increasing the starch content of cassava tubers was recorded by many workers like Blin (1905), Black and Cairns (1959), Lachover and Arnon (1962), Pillai (1967), Kumar et al. (1971), Obigbesan (1973), Pushpadas and Aiyer (1976), Rajendran et al. (1976), Asokan and Sreedharan (1977), Pillai and George (1978), Gomes et al. (1980), Nair et al. (1980) and Nair (1982). The reducing sugar content of tubers was also highest at 100 kg K_2O/ha (table 44). Scheck (1953) and Mengel (1975) reported the beneficial effect of potassium on sugar synthesis, translocation and deposition in storage organs. The HCN and fibre contents of tubers are reduced by application of potassium (tables 42 and 52 respectively). The effect of and Kumar (1980) and Nair (1982). The number of tubers per plant, length and girth of tubers, height of plant, girth of stem, length of petiole, total number of leaves produced, number of leaves retained and dry matter content of flesh and rind in the tuber were higher at a potash level of 100 kg K_2O/ha (tables 30, 31, 32, 33, 34, 35, 36, 37, 39 and 40). Similar results were reported by Pillai (1967), Magoon et al. (1972), Thamburaj and Muthukrishnan (1976), Ngongi (1976), Nair and Balagopal (1978), Pushpadas and Aiyer (1976), Asokan and Sreedharan (1977 and 1980), Anker et al. (1980), Edwards (1982), Nair (1982) and IITA (1982). Maximum starch content of tubers is recorded by 100 kg K_2O/ha eventhough it is not significantly different from K_2O @ 150 and 300 kg/ha (table 43). The effect of potassium in increasing the starch content of cassava tubers was recorded by many workers like Blin (1905), Black and Cairns (1959), Lachover and Arnon (1962), Pillai (1967), Kumar et al. (1971), Obigbesan (1973), Pushpadas and Aiyer (1976), Rajendran et al. (1976), Asokan and Sreedharan (1977), Pillai and George (1978), Gomes et al. (1980), Nair et al. (1980) and Nair (1982). The reducing sugar content of tubers was also highest at 100 kg K_2O/ha (table 44). Scheck (1955) and Mengel (1975) reported the beneficial effect of potassium on sugar synthesis, translocation and deposition in storage organs. The HCN and fibre contents of tubers are reduced by application of potassium (tables 42 and 52 respectively). The effect of potassium on the reduction of HCN content in cassava tubers has been reported by Obigbesan (1973), Pushpadas and Aiyer (1976), Asokan and Sreedharan (1977), Nair *et al*. (1980), Muthuswamy and Chiranjivi Rao (1981) and Nair (1982). Muthuswamy and Chiranjivi Rao (1981) also reported that potash application decreased the fibre content of cassava tubers at maturity.

Starch characters like amylose content, granule size, pasting temperature, viscosity and swelling volume are found to increase with the increase in the level of potassium (Tables 45, 46, 48, 49 and 50). The cooking quality also is found to improve as the levels of potassium increase (table 79). Moorthy and Maini (1980) reported that amylose content is one of the most important factor having positive correlation with cooking quality. In the present study also, variety M-4, which is reputed for good cooking quality records significantly higher amylose content than var. H-2304. Moorthy and Maini (1980), studying the differences in properties of cassava starch found that the above characters viz., amylose content, granule size, pasting temperature, viscosity and swelling volume increased as the cooking quality of the tuber improved. IITA (1981) reported a positive correlation between applied K and size of storage cell in cassava tubers. It may be noted that application of potassium increases the granule size of cassava starch, which in turn increases the swelling volume and hence the improvement in cooking quality.

The study thus reveals the necessity for application of potassium for higher yields and better quality in cassava. Though improvement in quality is observed upto 200 kg K_2O/ha economic yield has to be compromised with quality. Considering the above points, a level of 120.05 kg K_2O/ha is found to be optimum for cassava in red loam soils of Vellayani.

Summary

SUMMARY

Investigations were conducted to find out the optimum dose and time of application of K in relation to yield and quality of cassava.

For this purpose a basic study on the effect of time and duration of supply of K to cassava plants was conducted in a sand culture experiment with nutrient solutions. Treatments were also included to find out the visual and chemical changes in the plant when potash was not included in the nutrient solution. Potassium was supplied at 1½ months interval from 0 to 4½ months in all combinations. Apart from these treatments K was supplied for 0 - 4½ months, 0 - 10 months and 4½ - 10 months. Including a no potash control there were 9 treatments in C.R.D. with 3 replications.

As an applied study with varying levels of potassium, a micro plot field experiment was conducted after taking two crops of cassava without applying potassium and thus bringing down the available K to a very low level. The exhaustion was considered necessary to enable greater accuracy in the incremental responses. The design was R.B.D. with 3 replications and the varieties were H-2304 and M-4. The different levels of potassium tried were 0, 50, 100, 150 and 200 kg K_2O/ha. The exhaustion was carried out in 1977-1978 and the response study in 1979-'80

respectively. The results are summarised below:

1. Among the different durations of potassium application, the maximum yield is obtained for the treatment wherein potassium was applied from the time of planting upto 4½ months.

2. The number of tubers per plant, length and girth of tubers, height of plant, girth of stem, length of petiole, total number of leaves produced and number of leaves retained, dry matter content of flesh and rind in tuber and starch and sugar contents in tuber are maximum in 0 - 4½ duration of potassium application.

3. The hydrocyanic acid and fibre contents of tubers are minimum in the treatment receiving potassium from 0 - 4½ months.

4. The amylose content, granule size, pasting temperature, viscosity and swelling volume of starch are higher in tubers obtained from potassium application from 0 - 4½ months duration.

5. Potassium deficiency in cassava is characterised by a severe reduction in plant height, girth of stem, short petioles and small leaf blades. Border necrosis of older leaves and brown discoloration in petioles are other symptoms noticed.

6. In potassium deficient cassava plant, the concentration of this element in the youngest fully expanded leaf is found to be 0.38 - 0.50 per cent.

7. The uptake of potassium by cassava is maximum for 0-10 months duration of K application, while the maximum yield is for 0 - 4½ months duration of its application. This shows a luxury consumption of potassium by cassava.

8. The uptake of nitrogen and phosphorus is not much influenced by the duration of potassium application.

9. Among the different levels of potassium, the maximum yield is recorded by 100 kg K_2O/ha for both the varieties viz., H-2304 and M-4.

10. The number of tubers per plant, length and girth of tubers, height of plant, girth of stem, length of petiole, total number of leaves, number of leaves retained and the dry matter content of flesh and rind of tubers are found to be maximum at a level of 100 kg K_2O/ha.

11. The starch, sugar and amylose contents of tubers are maximum and the HCN and fibre contents minimum at a potash level of 100 kg K_2O/ha.

12. The pasting temperature, viscosity, swelling volume and granule size increase as the level of potassium increase.

13. The concentration of potassium in the leaf blade increases with increase in the level of potassium.

14. The concentration of potassium in the youngest fully expanded leaf was higher at 4th month stage of cassava crop when compared to 10th month stage.

15. The maximum concentration of nitrogen and phosphorus is in the leaf blade while that of potassium is in the petiole.

16. Even in a soil of very low available potassium status viz., 65.2 kg K_2O/ha, the maximum yield of cassava is obtained at a level of 100 kg K_2O/ha.

17. From path coefficient analysis of yield and yield components, it is seen that maximum direct effect influencing the yield is possessed by the total number of leaves retained till harvest. For the starch and starch characters, maximum direct effect is due to amylose content.

18. Higher levels of KCl (100 kg K_2O/ha) tended to reduce the yield of cassava in red loam soil.

19. The optimum value of potassium in the youngest fully expanded leaf blade of cassava at 4th month stage is 1.056 per cent for variety H-2304 and 1.034 per cent for variety M-4.

20. The critical level of potassium for cassava in red loam soil is 128.05 kg K_2O/ha.

21. The utilisation index of cassava increases with the increase in the level of potassium application.

22. The per cent of spider mite infested leaves in cassava decreases as the level of potassium application increase.

23. As the level of potassium application increases in cassava, the cooking quality of tubers also improves.

Based on the study it can be concluded that the critical period of K nutrition to cassava crop is upto 4½ months from planting. The number of splits that are desirable in the field will largely depend upon the economics of cultural and earthing up operations, loss of applied K due to torrential down pour of rain in the months of June-July for April planting and October-November for September planting and other factors causing fixation and release of potassium. But the basic information collected points to the need for adequate levels of K in the soil medium during the 3rd to 4½ month period of crop growth.

The various yield components in relation to yield indicate that about 128 kg K_2O/ha gives maximum yield for variety H-2304 and M-4. However the N:K ratios on the basis of N used will be 1:1.28 for both the varieties viz., H-2304 and M-4. The studies on quality indicate linear improvement in quality at levels greater than 100 kg K_2O/ha.

These results indicate the need for higher doses of K than at present advocated. But, increased use of K will have to be worked out in relation to cost benefit ratios particularly incremental cost benefit ratios. These considerations indicate that a dose higher than 128 kg K_2O/ha may become uneconomic.

Future lines of work

1. In sand culture experiment, the durations of potassium application can be combined with different levels of this nutrient and optimum for both can be established simultaneously.

2. As sources of potassium KCl and K_2SO_4 can be tried since at higher levels of KCl yield suppression due to chloride injury or probably chloride induced sulphur deficiency has been reported. Similar yield depression was observed in the present study. This requires detailed study.

3. The response of potassium and the critical level of soil potassium could be assessed in different soil types in which cassava is being grown.

4. The critical level of potassium in the leaf blade could be assessed for different varieties of cassava usually grown by the farmers and at different agroclimatic regions.

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*Original not seen

EFFECT OF POTASSIUM NUTRITION ON THE YIELD AND QUALITY OF CASSAVA (*Manihot esculenta* Crantz)

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ABSTRACT OF THE THESIS
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ABSTRACT

Investigations were carried out at the College of Agriculture, Vellayani to find out the optimum dose and time of application of potassium to cassava in relation to yield and quality. For this purpose a sand culture experiment with nutrient solutions at varying durations of K application and a microplot field experiment with different levels of K were conducted during 1977-1980. Before conducting the field experiment, two crops of cassava were taken in the same plot without applying potassium and thus bringing down the available K to a low level.

The maximum yield is recorded by 100 kg K_2O/ha (in conjunction with 100 kg each of N and P_2O_5 respectively) among the different levels of potassium tried and the optimum time of K application is found to be from the time of planting upto 4½ months for both the varieties H-2304 and H-4. The number of tubers per plant, length and girth of tubers, height of plant, girth of stem, length of petiole, total number of leaves, number of leaves retained and dry matter content of flesh and rind of tubers are found to be maximum at this level of potash for the same duration of application. The starch and sugar contents are higher and the HCN and fibre contents lower at a potash level of 100 kg K_2O/ha and for 0-4½ months duration of K application. From path coefficient analysis of yield and

yield components, it is seen that maximum direct effect in influencing the yield is possessed by the total number of leaves retained at the time of harvest. For the starch and starch characters maximum direct effect is due to amylose content. This is true in the case of 0-4½ months duration of K application also in the sand culture experiment. The per cent of spider mite infected leaves in cassava decreases as the levels of potassium increase. Potassium deficiency in cassava is characterised by a severe reduction in plant height, girth of stem, short petioles and small leaf blades. Border necrosis of older leaves and brown discoloration of petioles are other symptoms noticed. At higher levels of potassium the cooking quality and edible quality of cassava tubers improved.

The optimum level of potassium for cassava in red loam soil is 120.09 kg K_2O/ha.

The study thus high lights the need for potassium application for both higher yields and better quality in cassava. However, though linearity in improvement of quality is observed upto 200 kg K_2O/ha economic considerations in relation to yield has to be compromised with quality. Taking all these into consideration a level of 120.09 kg K_2O/ha is found to be suitable for cassava in the red loam soils of Vellayani.