STUDIES ON THE CRITICAL PERIODS OF WEED INFESTATION AND EFFECT OF WEED GROWTH ON YIELD AND QUALITY OF A SHORT DURATION RICE

BY

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THESIS

SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE
MASTER OF SCIENCE IN AGRICULTURE
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI - TRIVANDRUM

1978

DECLARATION

I hereby declare that this thesis entitled "Studies on the critical periods of weed infestation and effect of weed growth on yield and quality of a short duration rice" is a bonafide record of research work done by me during the course of research 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,
26th October, 1978.

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CERTIFICATE

Certified that this thesis, entitled "Studies on the critical periods of weed infestation and effect of weed growth on yield and quality of a short duration rice" is a record of research work done independently by Shri. Abraham Varughese, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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ACKNOWLEDGEMENTS

The author wishes to place on record his deep sense of gratitude and indebtedness to:

Shri. K.P. Madhavan Nair, Associate Professor of Agronomy, College of Agriculture, Vellayani, Kerala Agricultural University for his sincere guidance, critical suggestions and constant encouragements during the course of this investigation,

Dr. N. Sadanandan, Dean Faculty of Agriculture, Kerala Agricultural University for his helpful suggestions and criticisms,

Dr. C. Sreedharan, Professor of Agronomy, College of Agriculture, for his inspiring suggestions and encouragements,

Shri. E.J. Thomas, Professor of Agricultural Statistics for his helpful suggestions in designing the experiment and in analysing the data, Dr. (Mrs.) S. Kabeerathumma and Shri. Abdul Hameed, Division of Agricultural Chemistry for their helpful suggestions in chemical analysis,

All other members of the Division of Agronomy for their help during the course of this investigation; and

Parents and friends for their constant encouragements.

(ABRAHAM VARUGHESE)

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INTRODUCTION

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In the battle for higher yields agriculture has to face some perennial problems. Of the many factors limiting crop production, agricultural pests - animal diseases, plant diseases, insect pests and weeds - are the most important ones. Weeds are more detrimental to crop yields among the agricultural pests. The annual losses to Indian Agriculture from plant diseases, insect pests and weeds amount to Rs.5,000 crores (Gill and Brar, 1972) and weeds inflicted a loss of Rs.4,200 million, (Metha and Joshi, 1965). There is hardly a crop free from this pest and few people realise the burden caused by weeds. The loss in rice in India due to weeds was estimated as 15 million tonnes which was equivalent to 28 per cent of annual production of rice. (Gopalakrishna Pillai and Rao, 1974).

Crop weed competition is mainly for water, nutrients, sunlight and space. Many factors are involved in the crop weed competition such as crop variety, weed species, crop weed density, soil fertility, moisture, cropping season and other cultivation practices. The high yielding short statured rice varieties with a different crop geometry and canopy architecture have accentuated the problems of weed control in rice culture than with the tall leafy varieties, which could compete better with weeds due to its quick initial growth vigour.

In almost all the crops there is a certain period during their growth, when the competition from the weeds become very severe, which will adversely affect the crop growth and yield. This period may be termed as the critical period of weed competition in a crop. The critical period of weed infestation in rice was found to vary from 4 to 6 weeks after transplanting (Shetty and Gill, 1974) and 10 to 30 or 40 days after seeding in uplands (Ghosh et al. 1975).

Knowing the critical periods of a crop weed competition, will facilitate in planning weed control rationally, ie. weeding at the right time and for the required period or using the right herbicide which can control the weeds till the crop becomes established for maximum yield.

Weeds must be controlled at the right moment just before or as the factors for growth become limiting and should be continued until the crop becomes dominant, to get the deserved dividents from the time and money spent by the geneticists, soil scientists, entomologists and plant pathologists in raising the productivity.

Weed control is one of the major farm operations during the growing season of rice. Traditional manual methods of weed management are still the most effective approach in India. Chemical methods of weed control practice does not justify its adoption by an average rice farmer except in areas where the labour is costly and scarce and during the peak periods of farm operations.

In Kerala 59.70 per cent of the total holdings are less than 1 acre, which works out to 0.38 acre/holding (Farm Guide, Kerala 1978). Many of the paddy lands are few cents in dimensions and cultivated with the help of the family labour. Usually half to more than half of the total efforts in farming is for fighting the battle against vegetation. Hand weeding was found to be as effective as chemical weeding and so wherever chemical methods fail hand weeding may be adopted. Since no definite time schedule have been recommended for weeding farmers do the operations according to their discretion, availability of labour and resources.

The critical periods of competition varies with the crop variety, weed species and other agroclimatic conditions. Therefore the present study was undertaken using a short duration variety of rice Trivoni under transplanted condition during the second crop season 1976-'77 (September/October to December/January) in the Instructional Farm attached to the College of Agriculture, Vellayani with the following objectives.

1. To find out the tolerance and susceptability of the crop for weeds.

2. To find out the critical periods of crop weed competition, and to fix appropriate time and period for weed control.

3. To study the effect of weed control and weed competition on the yield and quality of rice.

4. To study the nutrient removal by crop and weeds.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Eventhough farmers are aware of the magnitude of crop losses caused by weeds, they do not give necessary importance in controlling them. Weeds not only reduce crop yields but also reduce the quality of the produces.

On a closer observation of the phenomenon of crop weed competition one can find that there are certain periods in the crop growth, when the field should be kept free of weeds for maximum crop yields. The present study was undertaken to determine the critical period of crop-weed competition in a transplanted short duration rice, during the second crop season. Literature on various aspectes of crop-weed competition is reviewed under.

1. Weed spectrum in rice-fields

Weeds found in the rice fields were grouped as grasses, sedges and broadleafed plants.

Dixit *et al*. (1968) observed 119 weed species growing in Gorakpur, paddy fields, representing 33 families, out of which 72 were dicotledonous and 47 were monocotyledenous plants.

Eue (1972) studying the weed problems in rice reported that the estimated 135.5 million hectares of rice land supported about 400 weed species; *Echinochloa*, *Cyperus*, *Scirpus* and *Ischaemum* were considered to be the most important of the 18 main weed genera found in rice in at least two continents. The common weeds found in the wetland rice fields of Mancompu, Kerala State were *Echinochloa colonum*, *Fimbristylis miliacea* and *Cyperus rotundus* (Gopalakrishna Pillai and Rao, 1974). Maiti and Asima Lahiri Majumdar (1975) found that weeds in a crop field generally complete their life cycle along the life cycle of the respective crops and that the weeds in *kharif* do not occur during *rabi* season. The most important weeds found at the Rice Research Station, Pattambi, were *Echinochloa crus-galli*, *Brachiaria* sp., *Cleome* sp. and *Fimbristylis miliacea* (Nair *et al*. 1975).

Weeds in rice fields were identified and reported by various workers, like Anon. (1970 a), Patro *et al*. (1972), Chang (1973), Ray (1973), Smith (1973), Gupta and Soodan (1975), Maiti and Asima Lahiri Majumdar (1975), Shetty *et al*. (1975) and Ravindran (1976). Some of the important weeds reported by the above workers are listed below.

1. Grasses	*Echinochloa crus-galli* (L) Beauv.
	Echinochloa colonum (L) Link.
	Oryza sativa var. fatua (L)
	Panicum repens.L.

Dactyloctenium aegyptium (L) Beauv.

Paspalum distichum L.

Setaria glauca (L) Beauv.

Eleusine indica (L) Gaertn.

Brachiaria ramosa (Grisob) Stapf.

Ischaemum rugosum Salisb.

Eragrostis major (Beauv) Host.

Leptochloa panicoides (Presl.) Hitchc.

Eleocharis acicularis (R.Br.)

Cynodon dactylon (L) Pers.

2. Sedges

Cyperus difformis L.

Cyperus iria L.

Cyperus haspan L.

Cyperus rotundus L.

Fimbristylis miliacea (L) Vahl.

Scirpus maritimus L.

Scirpus articulatus L.

3. Broadleafed weeds

Sphenoclea zeylanica Gaertn

Ammannia baccifera L.

Sesbania exaltata (Rof) Cory.

Ipomoea spp. (L)

Monochoria vaginalis Presl.

Oxalis corniculata L.

Alternanthera sessilis (Forsk) R.Br.

Oldenlandia corymbosa (Plum)L.
Ludwigia parviflora (L) Roxb.
Rotala indica (L) Koehne.
Leucas aspera (R.Br.) Spr.
Phyllanthus niruri L.
Portulaca oleracea L.
Salvinia molesta De. Mitchel

2. Losses in production due to weeds

Weeds are major barriers to food production and economic development in many regions of the world, particularly in underdeveloped countries. They reduce yields, impair the quality of the produce and increase the cost of production.

Kramer (1967) reported that the annual losses in rice grain in India due to weeds as 10.8 per cent of potential production or 25 per cent of actual production.

Mani et al.(1968) reviewing the yield losses due to weeds in India found that losses in rice varied from 9-51 per cent. Thakur (1969) reported that the annual loss in India due to weeds might be to the order 2.4 million tonnes of rice worth about Rs.792 million. Multilocation trials conducted in India revealed that the reduction in yield of rice due to weeds alone was to the tune of 15-20 per cent for transplanted rice, 30-35 per cent for direct seeded rice under puddled condition and over 50-60 per cent for upland rice (Gopalakrishna Pillai and Rao, 1974). They also reported that the potential loss in production of rice in India on account weed infestion as 15 million tonnes per annum which is equivalent to 28 per cent of annual production of rice.

3. Methods of weed control

Physical operations such as hand weeding, hoeing and use of other agricultural implements together with cultural operations, crop rotation, crop competition, etc. are the traditional methods of weed management most widely practiced in India. Chemical methods of weed control has not yet received much impact in Indian Agriculture due to various reasons.

Anon.(1965) reported that in upland rice hand weeding is effective and widely practiced. Hand weeding on 15th day after sowing required 240 man hours/ha but hand weeding on 45th day after seeding required 780 man hours/ha. Anon (1967) reported that in tropical Asia, hand weeding is by far the most common method of weed control in flooded rice. Experiments at IRRI also stressed that hand weeding should be properly timed to reduce weed population and to minimise man hours for weed removal. Mieto *et al*. (1968) recommended hand weeding as the method to determine the critical period of crop weed competition in crops with a uniform weed population in all the plots. Soerjani et al. (1969) recommended hand weeding as a practical method in small farms and chemicals for large farms. Peters (1972) reported that by using the existing hand weeding methods it was possible to determine the onset and duration of weed competition in a crop. Hand weeding and the use of rotary weeder were the methods most widely practiced in Philippines and other Asian countries to control weeds in transplanted rice. (Anon.,1974)

Scolari and Young (1975) concluded that for small holders, using family labour, traditional manual methods remain the most economical method of weed control. Bibbas Ray (1976) reported that hand weeding is the main practice in India, and that chemical methods in India is applicable during peak periods, labour scarcity areas, and in soil conditions unfavourable for manual and mechanical weeding.

4. Crop weed competition

Weed damage to crop varied with weed species, crop variety, duration of infestation of weeds, season, level of soil fertility, soil water relations, plant protection measures and other cultural practices. In general crops and weeds compete for water, nutrients and light.

Anon. (1968) reported that competition was most serious when a mixed weed community was present during the early stages of transplanted rice and that IR-8 was more susceptable to weed competition than H-4. Datta *et al.* (1968) found that grassy weeds were most influential in reducing grain yield, followed by broad-leafed species and then by sedges. Anon. (1970 a) pointed out the critical period of crop-weed competition was influenced by the variety, the rate of growth and the crop-weed density.

Chang (1970 and 1970 a) found that among the major weeds of rice, *Echinochloa crus-galli* caused the most damage followed by *Cyperus difformis* and *Monochoria vaginalis*. Muzik (1970) reported that weed competition was most serious when crops were young and that a moderate infestation is sometimes as serious as a heavy infestation. Chang (1973) reported that yield reductions caused by weeds varied with weed density, weed species, crop season, level of soil fertility and variety being grown.

a. Critical periods of crop weed competition

Experiments at IRRI proved that timing of weed control was as important as other cultural practices and found that a single weeding 2 weeks after planting cv. *Palawan* gave best yields. (Anon., 1964) and that weed competition for 15 - 25 days reduced rice yields sharply and maximum competition occured 25-45 days after seeding upland rice (Anon, 1965).

Anon. (1967) reported that competition beyond 42 days after transplanting rice (IR-8) was most critical and found that hand weeding on 21st day was most economical. Burnside and Wicks (1967) concluded that when sorghum was kept weed free for the first 4 weeks only, there was little yield loss from later emerging weeds. Weeds not removed until four weeks after planting plus each week thereafter reduced sorghum yields significantly. Vega et al. (1967) found that weed control for 40 days after sowing upland rice produced highest yield (3 t/ha) and weed competition for first 30-50 days reduced yield by 6.5 - 62.0 per cent compared with weed competition for the first 10 days. Competition for 40 or more days caused significant yield reductions.

Bhan et al. (1969) concluded that weed free condition upto 45 days after seeding gave yields similar to full season weed free crops. The rice-weed competition was influenced by the rate of growth and crop density as indicated by studies at IRRI, where in it is found that cvs. IR-8 and C4-63, tolerated weeds during 20-30 days and 30-40 days, respectively after transplanting and the minimum weed free period of 20 and 30 days were required for optimum yields for the cultivars (Anon, 1970 a). Weed competition substantially influenced grain yield during the first 30 days after transplanting paddy rice (wetland rice) and the first 50-60 days of the sowing upland rice (Park and Kim, 1971).

Bhan *et al.* (1974) reported that weeding the rice crop at 30 days after drilling or any combination of 2 weedings (15 + 30, 30 + 45, 15 + 45) and (15+30+45) days after sowing gave grain yields equal to that obtained from weed free conditions. Weeding 30 - 45 days was generally sufficient to avoid appreciable yield losses in direct sown sorghum, bajra and transplanted rice (Panchal and Sastry, 1974). Shetty and Gill (1974) showed that the most critical period of crop weed competition in transplanted rice was between 4-6 weeks since, maximum grain yield of 5635 kg/ha was obtained when weeds were removed 4 weeks after transplanting.

Smith (1974) reported that *Echinochloa crus-galli* competition for 10 or 20 days did not reduce grain yield of any cultivar and that the weed competition for 40 days or longer, reduced yields of rice cvs. *Nova* 66 and *Bluebelle* and competition for 60 days or longer lowered yields of cv. *Starbonnet*.

Ghosh *et al.* (1975) reported that the period between 10 days to 30-40 days after seeding cv. *Ratna* appeared the most vulnerable, when serious reduction in yield occured in weedy plots. Nair et al.(1975) observed that the longest period of weed competition, a direct seeded upland rice could tolerate, was 30 days from sowing, without adverse effect on yield and that weed competition was more critical during early vegetative phase of the crop. Swain et al.(1975) concluded that weed removal prior to tillering gave higher yields than after tillering. Dubey et al.(1977) observed maximum weed competition in rice during the first 3 weeks and competition decreased thereafter till 9 weeks when reduction in grain yield due to weed competition was negligible. Mohamed Ali et al.(1977) reported that a weed free condition upto 21 days from planting caused more productive tillers and yield in rice and maintaining a weed free condition beyond 3 weeks did not enhance yield significantly. The most critical period, when crop losses due to weed competition was most severe, ranged from 10 - 20 days after emergence in upland rice. (Sharma et al. 1977)

b. Competition for water

Kaul and Raheja (1952) reported that transpiration coefficients were 556 for *Ischaemum pilosum*, 813 for *Cynodon dactylon*, 1108 for *Tephrosia purpurea* and 1042 for *Tridax procumbens*, while it was only 432 for sorghum. Misra and Vijayakumar (1962) noted that at 6 inches soil depth the moisture in unweeded plot was 2.5 per cent in a bajra crop as against 4 per cent in the weeded plot.

Meggit (1970) reported that about 500 lb of water was required to produce 1 lb of plant dry matter (maize) and a weed infestation of 500 - 1000 lb dry matter per acre would require 1-2 acre inches of water. Fadenov and Andruev (1974) reported that weeds may utilise 2-3 times more of the available nutrients and water than the flax crop. Abbas Ray (1976) stated that the amount of water used in transplanted rice could not be necessary if weeds were not there.

c. <u>Competition for nutrients</u>

Subba Rao (1966) observed that competition between weed and crop was mainly for nutrients than for moisture and light. It was found that there was an inverse relationship between weed and crop dry matter production in *Gora* paddy. Swain (1967) reported that *Echinochloa* sp. absorbed more nitrogen than did rice crop. Noda *et al*. (1968) observed maximum competition for nitrogen during the first half of the growing season between rice and barnyard grass.

Datta *et al*. (1969) reported maximum competition for nitrogen by weeds during early stages of growth of rice and that high fertility benefited weeds more than the rice crop. Mikkelson (1970) noticed that the nitrogen accumulation in rice was rapid at vegetative phase and 3/4th of it occured by grain formation. Whereas P absorption was continuous and only less than half of it occur before panicle initiation and a period of maximum P requirement occured between panicle initiation and heading. He also found that K uptake in rice was faster than N and P and that by booting 3/4th of it was absorbed. Chakraborty (1973) found that weeds competed with rice throughout the growing season for nitrogen and that 3 hand weedings increased N content of rice. Mallappa (1973) opined that nitrogen uptake by rice was inversely proportional to the nitrogen uptake by weeds in drillsown rice. Rethinam et al. (1974) noted that dry matter production of rice was significantly reduced in unweeded crops as compared to weed free crops. Shetty and Gill (1974) observed that both the weeds and crops competed for the nutrients to the maximum during the early period of growth and that the competition for soil nitrogen was maximum during 6-8 weeks after transplanting rice. They also found that weeds were more efficient in nitrogen uptake than the crop whereas rice was more efficient in absorbing phosphates and potash.

Okafor and Datta (1976) reported that total nitrogen uptake by purple nutsedge negatively correlated with rice grain yield for all levels of nitrogen at all seasons ($r = -0.720$).

d. Competition for light and space

King (1966) reported that the rate of growth of certain weed species enabled them to suppress the growth of crop plants and eventually to crowd them out altogether.

Arai (1967) reported that competition for light began as early as 20 days after transplanting rice and is dependent on early growth rate and size of weeds, and that competition was serious at later stages of crop growth. Noda et al. (1968) found that highest density of barnyard grass reduced light intensity by 70 per cent in rice. Smith (1968) reported that barnyard grass shaded rice early during the growing season since it was usually as tall as rice and competition was purely for light and nutrients when water was not limiting. Kawano et al. (1974) reported that with normal supply of nitrogen, plants competed primarily for light. Usually the effect of competition for light was much greater than that for nitrogen in rice populations.

5. Effects of Crop-Weed Competition

a. Effect on growth and yield characters

Pande and Bhan (1966) reported that the leaf area index of upland rice increased by weeding. Anon. (1967) reported that generally the time of weed emergence did not affect plant height, though it affected the dry matter production when sown with rice.

Arai (1967) found that *Echinochloa crus-galli* competition reduced the number and weight of panicles, number of spikelets per panicle and percentage of ripe grains, whereas *Monochoria vaginalis*, *Rotala indica* and *Cyperus difformis* reduced the panicle number only, in transplanted rice. Swain (1967) opined that barnyard grass reduced tiller number of rice by 45 per cent. Kleing and Noble (1968) reported reduced number of rice tillers, panicles and spikelets per panicle, but the percentage of grainfilled spikelots was unaffected due to *Echinochloa* competition. Noda *et al.* (1968) noted that the number of panicles was the most important factor reducing rice yields, followed by 1000 grain weight, and number and fertility of spikelets.

Main and Rahman (1969) concluded that weeds left unweeded in transplanted rice reduced the number of ears per hill, the number of grains per panicle, and ultimately the grain yield by 22 per cent compared to hand weeding. Chang (1970 and 1970 a) reported that panicle number suffered most followed by number of grains per panicle in rice due to weed competition and that the 1000 grain weight and fertility percentage were only slightly affected. Misra and Roy (1970) noted a suppression in the height of rice plants due to weeds in highland rice. Main and Gaffor (1971) reported that in unweeded plots the number of ears per hill

(7.1) and numbers of grains per ear (86.8) were significantly different from hand weeded plots in rice with 9.1 ears per hill and 108.4 grains per ear. The 1000 grain weight was not affected by weed infestation. Noda et al. (1971) reported that barnyard grass competition at tillering stage reduced the number of panicles and the yield of rough rice and competition at later stages reduced kernel weight and number of kernels. Chang and Datta (1972) noted reduced plant height (52.4 cm), number of tillers per hill (21.2) and panicle per hill (12.5) in unweeded control as against plant height of 54.1 cm and number of tillers per hill (27.8) and number of panicle per hill (17.6) in hand weeded plots in transplanted rice. Chang and Mao (1972) observed that prolonged weed competition reduced the number of panicles and the number of grains per panicle.

Yogeswara Rao and Padmanabhan (1972) noted that, in transplanted rice, cv. IR-8, grains per panicle was most affected by weed competition (107) as against grains per panicle in hand weeded plots (130) and that the 1000 grain weight was unaffected. Ramamoorthy et al. (1974) reported that number of productive tillers in rice was reduced by weed competition. Rethinam and Sankaran (1974) found that weed competition reduced plant height in rice. Shetty and Gill (1974) observed that weed competition did not affect plant height and number of tillers in transplanted rice, but the length of panicle was reduced. Mohammed Ali and Sankaran (1975) reported that eventhough weed competition reduced plant height in transplanted rice it was not significant. The number of productive tillers/m^2 in unweeded control was 77 and in hand weeded plots it was 117. Swain et al. (1975) reported that weed removal at early tillering stage increased tiller number by 75 per cent and yield by 74 per cent while weeding after tillering resulted in 39 per cent increase in yield, without significantly affecting tiller numbers. Narayanaswamy (1976) reported a reduction in number of tillers, panicle number and number of grains per panicle due to unchecked weed growth in transplanted rice. Ravindran (1976) reported that the weed competition reduced the effective tillers/m^2, percentage of productive tillers, weight per panicle, and the percentage filled grains per panicle, but 1000 grain weight and length of panicle were unaffected. Plant height and tiller number was also unaffected by weeds in rice. Sharma et al. (1977) reported that in general plant height, number of effective tillers, and grains per panicle increased as the weed free period was prolonged and decreased as the weed infestation period was extended in transplanted rice. Panicle length was not affected by weed competition.

b. Effect on yield and quality

Delay in hand weeding beyond 2 weeks after transplanting cv. Palawa reduced 24 kg/ha of rice per day (Anon, 1964) and delay in weeding beyond 15 - 25 days sharply reduced upland rice yields at the rate of 43 kg/ha per day from 25th to 45th day after seeding. (Anon, 1965). Anon.(1967) found that weeding transplanted rice cv. IR-8 on 42nd day gave maximum yield (8290 kg/ha) compared to weeding on 21st, 28th, 35th, 49th, 56th and 63rd day after transplanting.

Ghosh and Pande (1967) got a high negative correlation between grain yield of rice and weight of weeds. Anon. (1968) observed that grain yield data compared inversely with weed community densities as measured by weed weights. Datta et al. (1968) got a correlation coefficient of -0.87 between total weeds and yields in transplanted rice. Noda et al. (1968) found that rice yield reduction was closely related to increase in the total dry weight of barnyard grass and density of population. Chang (1970 a) observed that grain yield reductions were 69, 47, 28 and 11 per cent in the first crop and 52.5 and 13 per cent in the second crop, when weed emergence was delayed by 15, 30, 45 and 60 days respectively in the first crop and 10 and 20 days respectively in the second crop in transplanted rice. Matsunaka (1970) reported 87, 84 and 81 per cent yield reduction from Echinochloa crusgalli, Monochoria vaginalis and Cyperus difformis respectively.

Grassy weeds at the rate of 200 gm dry matter/m^2 reduced yield of rice by 30 per cent.

Verma and Mani (1970) got a highly significant negative correlation between dry matter accumulation of grass weeds and grain yield of transplanted rice. Mukhopadhyay et al. (1971) reported 100 per cent loss of the crop in upland rice. Park and Kim (1971) found that in plots with mixed weed species comprising of Echinochloa crus-galli, Monochoria vaginalis and Cyperus iria, rice yields were reduced by 48 per cent as compared to weed free plots and reducing weed dry matter 80 - 85 per cent did not reduce yields. Bhan and Maurya (1972) observed that low weed population was sufficient to reduce rice yields (61.77 q/ha) in unweeded control when compared to weed free plots (81.66 q/ha). Chang and Moo (1972) observed that when weeds were removed at 15, 30, 45 and 60 days after transplanting in the first crop and 10, 20, 30 and 40 days after transplanting in the second crop, reduced yields by 0, 1.2, 12.2 and 38.9 per cent respectively in the first crop and 8.2, 32.4, 46.7 and 64.3 per cent respectively in the second crop. Cheng (1973) observed 15-31 per cent yield reduction in rice depending on weed density.

Bhan et al. (1974) in experiments at University of Agriculture and Technology, Pantnagar, proved that weeding direct seeded rice crop on 15th or 45th day was not effective compared to weed free check in increasing yields, but one weeding on 30th day or a combination of 2 or 3 weedings on 15th, 30th and 45th day gave yields similar to weed free check.

Panchal and Sastry (1974) observed that there was a reduction in yield on an average of 5, 10 and 15 per cent if the weed free environment was provided to the cereal crops for 30, 20 and 10 days after sowing. Rice yields of transplanted Jaya were 57.23 q/ha (weed free) 50.24 (weed free 1-10 days) 52.37 (weed free 1- 20 days) 54.29 (weed free 1-30 days) 57.44 (weed free 1-45 days) 45.39 (unweeded control), 53.97 (hand weeded crop) and 57.91 q/ha (chemical weeding). Shetty and Gill (1974) reported that delaying weeding beyond 4 - 6 weeks increased weed dry matter and decreased grain yield in rice. They also found that the grain yield reduction was of the order of 10 q/ha when the time of weed removal was extended for 6-8 weeks after transplanting. Full season weed competition reduced yields by 27.77 per cent during rabi and 15.87 per cent during kharif (Anon 1975). Swain et al. (1975) reported that the adverse effect of Cyperus difformis was linear from the date of appearance of the weed until the completion of rice tillering and yield reduction varied from 22-43 per cent due to weed competition. Ravindran (1976) noted 25.5 per cent yield reduction in transplanted rice due to weeds compared to hand weeded plots. Percentage weed weight reduction and percentage increase in grain yield were negatively correlated (Sharma et al. 1977).

Ramamoorthy et al. (1974) found that hand weeding as well as weed control with propanil gave higher protein content over unweeded control. Gomez and Datta (1975) observed that grain yield and protein content could be increased simultaneously but only upto a certain limit beyond which further increase in protein content resulted in a decrease in grain yield and that the major sources of variation in protein content were crop, season, location, nitrogen fertilisation, water management and weed control. Sankaran and Mani (1975) reported a highly significant negative correlation between uptake of nitrogen by weeds and seed protein yield of sorghum. Ravindran (1976) found that penoxalin (G) treatment and hand weeding gave the highest protein of 7.97 per cent compared to unweeded control. Kaushik and Mani (1977) found that method of planting or weed control with butachlor, MCPB and propanil did not affect the protein content of rice grain.

6. Nutrient uptake by crop and weeds

Boerma (1963) reported that reduction of weed competition by propanil application resulted in an increased absorption of nitrogen almost three times by rice. Mukhopadhyay (1965) found that weeds in rice and wheat in unweeded control removed 19.38, 2.65 and 25.52 lb/acre of N, P_2O_5 and K_2O respectively. Swain (1967) noted that barnyard grass in rice fields removed 60-80 per cent of nitrogen from the soil and in the absence of the weed N absorption by rice increased 3 times.

Verma and Mani (1970) reported that unchecked weed growth depleted soil nutrients to the extend of 20, 11.8 and 20 kg/ha of N, P and K in rice crop and found that weed control by stam F-34 (2 kg/ha) brought down the nutrient depletion by weeds to 1.6, 1.0 and 2.4 kg/ha of N, P and K respectively. Chakraborty (1973) found that weeds in dular rice removed 29.9 and 30.9 kg N/ha in two years and 3 hand weeding brought down the nitrogen depletion to 2.66 and 9.88 kg/ha. In TN-1 rice, weeds removed 3.28 and 51.7 kg N/ha in hand weeded and control plots respectively where as rice removed 28.3 and 4.83 kg N/ha in hand weeded and control plots respectively. Sankaran et al. (1974) observed that weeds in unweeded control removed 62.1, 20.0 and 65.3 kg N, P and K/ha in rice. Shetty and Gill (1974) reported that the total uptake of nutrients by the crop and the weeds together in unweeded plots was less than the uptake of nutrients by the crop alone in weed free treatments.

Mani (1975) found that in wheat, peas, potato, rice, maize, soyabean and sorghum, weeds assimilated substantial amounts of nitrogen within 5 - 6 weeks of sowing the crops and the nutrient uptake was higher in kharif than in rabi season. Weeds in rice removed 23.3, 14.1 and 22.6 kg/ha of N, P and K during 1966 and 20.7, 9.5 and 17.5 kg/ha of N, P and K during 1967. Weed control increased the uptake of nitrogen by rice by 9.2, and 13.7 kg/ha during the two year by physical weeding, by 25.6 and 21.7 kg/ha. of nitrogen during 1966 and 1967 by chemical weeding. Sankaran and Mani (1975) got a highly significant negative correlation between nutrient uptake (N, P_2O_5 and K_2O) by sorghum and weeds. Ravindran (1976) reported that unchecked weed growth depleated soil nitrogen to the extent of 20.86 kg/ha while a single application of penoxalin (G) (1.5 kg a.i./ha) brought down the uptake of nitrogen by weeds to 0.96 kg/ha and considerably improved the uptake by crop (99.55 kg N/ha), while unchecked weed growth resulted in an uptake of 65.54 kg N/ha by crop. Balu (1977) reported that uptake of N, P and K was more for cv. Co-37 rice than for ADT-37. Among weed control treatments butachlor and penoxalin recorded higher uptake of nutrients by rice and was more in summer season. Grain yield showed a negative correlation with dry matter of weeds and with N, P and K uptake of weeds(-0.6553,

-0.6374, -0.6562 and -0.6522). Kakati and Mani (1977) observed that nutrient uptake by weeds was as high as 24.0, 5.1, and 48.4 kg/ha of N, P and K respectively in weedy check under direct seeded rice and 4.2, 0.8 and 6.9 kg/ha of N, P and K under transplanted rice.

MATERIALS AND METHODS

MATERIALS AND METHODS

A trial was conducted at the College of Agriculture, Vellayani to study the critical periods of weed competition and the effect of weed growth on yield and quality of a short duration rice var. Triveni during the second crop season.

Experimental site

The area was selected on the western side of the Agricultural College Farm, with facilities for controlled irrigation and drainage.

Season

The experiment was conducted during the second crop season (October to January) of 1976-'77.

Climatology of the crop

The meteorological factors recorded were rainfall, maximum and minimum temperature and relative humidity. The average weekly values and its variation from the past 5 years from sowing in the nursery to harvest were worked out and presented in Appendix I and Fig.1.

The total rainfall received during the crop season was only 8.72 cm less than the past 5 years average. But rainfall distribution was not normal. Of the 63.82 cm of rain fall received 41.71 cms and 7.28 cms were received during the 7th and 9th weeks respectively and there were no rain during the last 5 weeks of the crop season. This variation in the rainfall distribution did not affect the experiment much, since controlled drainage and irrigation facilities were available. But the third replication was destroyed by flood water inundation resulting from the excess rains received during the early stages of the crop and so had to be eliminated.

With regard to temperature, the maximum temperature was generally higher than the past 5 years' and the minimum temperature and relative humidity did not show much variations.

Soil

The soil of the experimental site was sandy clay in texture with the following physical and chemical compositions.

Physical composition

Coarse sand	43.40 per cent
Fine sand	19.72 per cent
Silt	4.22 per cent
Clay	31.62 per cent

Chemical composition

Total Nitrogen	0.0965 per cent (Micro Kjeldahl method)
Available P_2O_5	31 ppm (Bray's method)

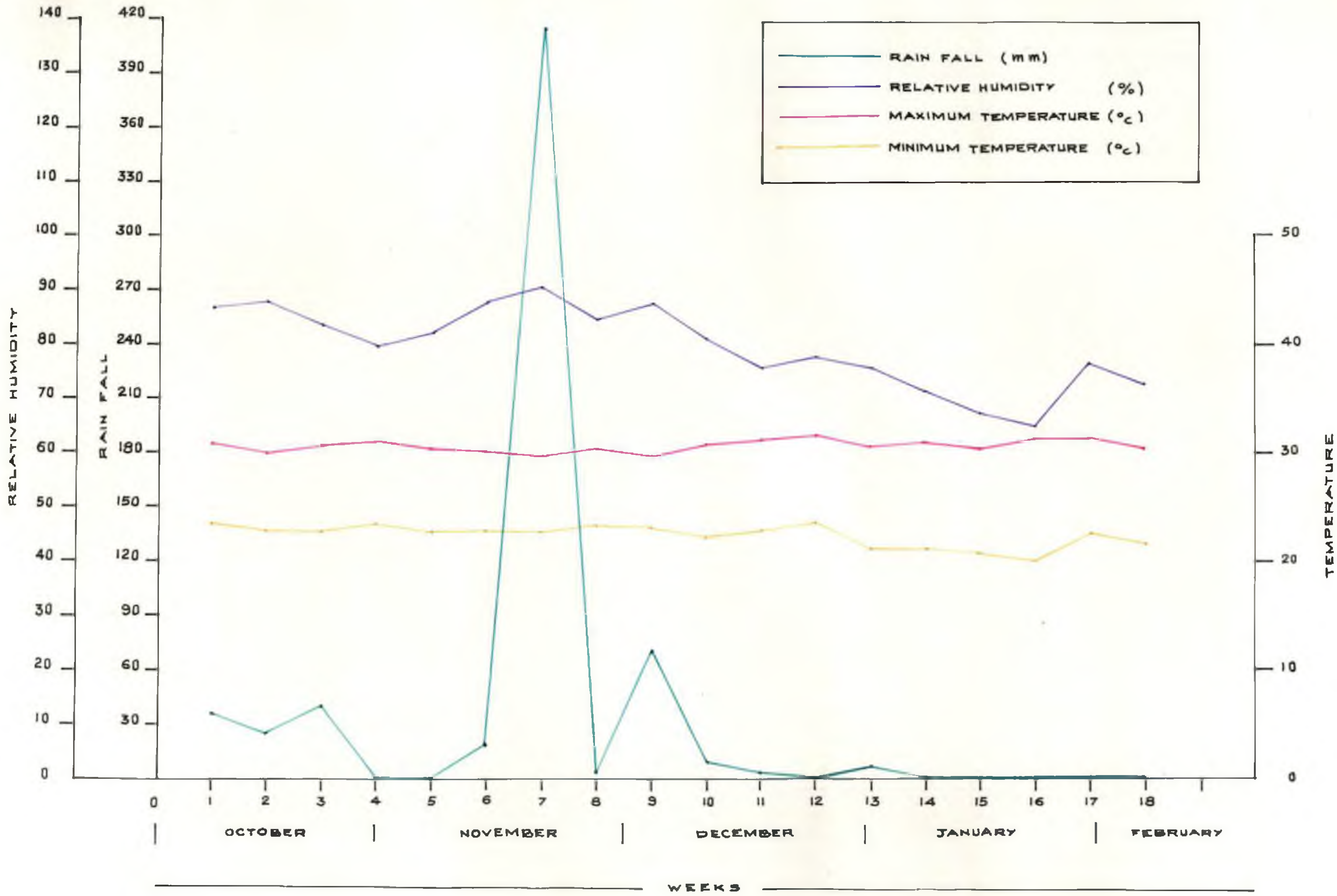


FIG. 1. WEATHER CONDITIONS DURING THE CROP SEASON 3rd OCTOBER 1976 TO 5th FEBRUARY 1977.

Available K_2O	36 ppm (Ammonium acetate method)
p^H	5.3 (1:2 soil solution ratio using pH meter)

Cropping history of the experimental plot

The experimental area was under a bulk crop of paddy during the previous year.

Rice variety

The variety selected for the experiment was *Triveni*; the progeny of a cross between *Annapurna* and ptb-15, released by Rice Research Station Pattambi. *Triveni* matures in 95 - 100 days. It is a short duration, high yielding variety with moderate tillering ability. The panicles are long and the grains short and bold. Rice is white and milling and cooking qualities are good. It is widely cultivated by farmers during all the three seasons.

Rice seeds

Seeds with 95% germination were obtained from Rice Research Station, Kayamkulam.

Weed seeds

Mature seeds of *Echinochloa crusgalli* were collected from the previous crop of rice.

Fertilisers

Ammonium sulphate, super phosphate and muriate of potash with 20.50 per cent N, 16.00 per cent P_2O_5 and 60.00 per cent K_2O respectively were used for the experiment.

Experimental Technique:

Simple Randomised Block Design was adopted. The experiment comprising of 17 treatments, was replicated 3 times. The layout plan is given in Fig. 2 and the diagramatic representation of the various treatments in Fig.3.

	Treatment	Abbreviations
1.	Weed free from 1-10 days after transplanting (D.A.T.)	T_1
2.	Weed free from 11-20 D.A.T.	T_2
3.	Weed free from 21-30 D.A.T.	T_3
4.	Weed free from 31-40 D.A.T.	T_4
5.	Weed free from 41-50 D.A.T.	T_5
6.	Weed free from 51-60 D.A.T.	T_6
7.	Weed free from 1-20 D.A.T.	T_7
8.	Weed free from 11-30 D.A.T.	T8
9.	Weed free from 21-40 D.A.T.	T_9
10.	Weed free from 31-50 D.A.T.	T_{10}

11.	Weed free from 41-60 D.A.T.	T_{11}
12.	Weed free from 1-30 "	T_{12}
13.	Weed free from 11-40 "	T_{13}
14.	Weed free from 21-50 "	T_{14}
15.	Weed free from 31-60 "	T_{15}
16.	No weeding (weedy check)	T_{16}
17.	Weed free from 1-60 D.A.T.	T_{17}

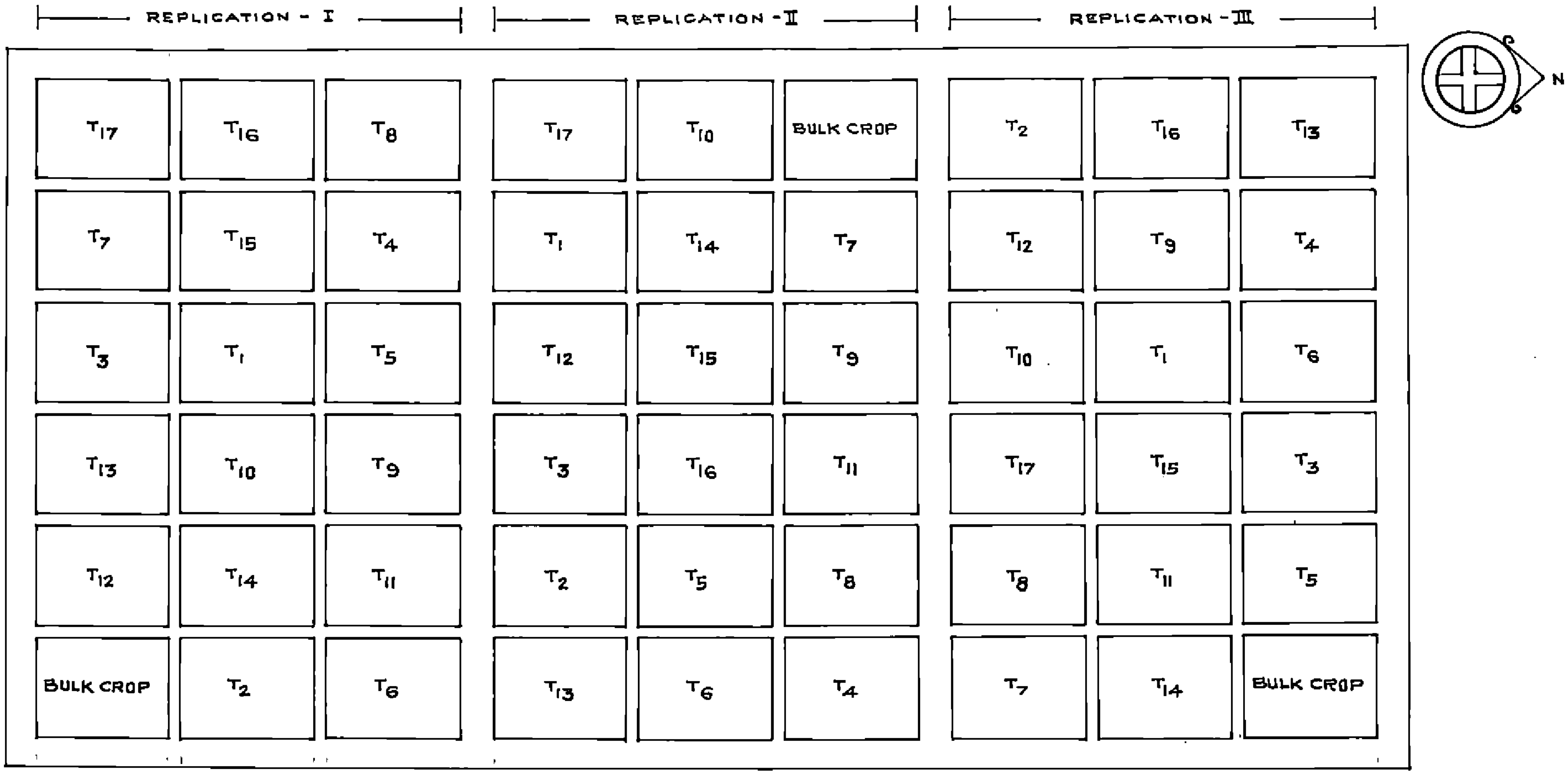
Total number of treatments in one block	17
Number of blocks	3
Total number of plots	51
Gross plot size	6 m x 4 m
Weed observation plot size	1.2 m x 4.0 m
Net plot size	4.2 m x 3.6 m
Net area of the plot	15.12 m^2
Total experimental area per replication	408 m^2
Number of border rows	2
Number of plants per hill	2
Spacing	15 x 10 cm

Hand weeding

Hand weeding was done on the 1st day and subsequently at 5 days interval depending on the treatments.

Field culture

The cultivation practices as recommended in the package of practices 1976 prepared by the Kerala Agricultural University were followed.



TREATMENTS

T_1 WEED FREE 1 - 10 DAYS
T_2 WEED FREE 11 - 20 DAYS
T_3 WEED FREE 21 - 30 DAYS
T_4 WEED FREE 31 - 40 DAYS
T_5 WEED FREE 41 - 50 DAYS
T_6 WEED FREE 51 - 60 DAYS
T_7 WEED FREE 1 - 20 DAYS
T_8 WEED FREE 11 - 30 DAYS
T_9 WEED FREE 21 - 40 DAYS
T_{10} WEED FREE 31 - 50 DAYS
T_{11} WEED FREE 41 - 60 DAYS
T_{12} WEED FREE 1 - 30 DAYS
T_{13} WEED FREE 11 - 40 DAYS
T_{14} WEED FREE 21 - 50 DAYS
T_{15} WEED FREE 31 - 60 DAYS
T_{16} UNWEEDED CONTROL
T_{17} WEED FREE 1 - 60 DAYS

GROSS PLOT SIZE 6 X 4 M
NET PLOT SIZE 4·2 X 3·6 M

FIG. 2. LAY OUT PLAN - RANDOMISED BLOCK DESIGN

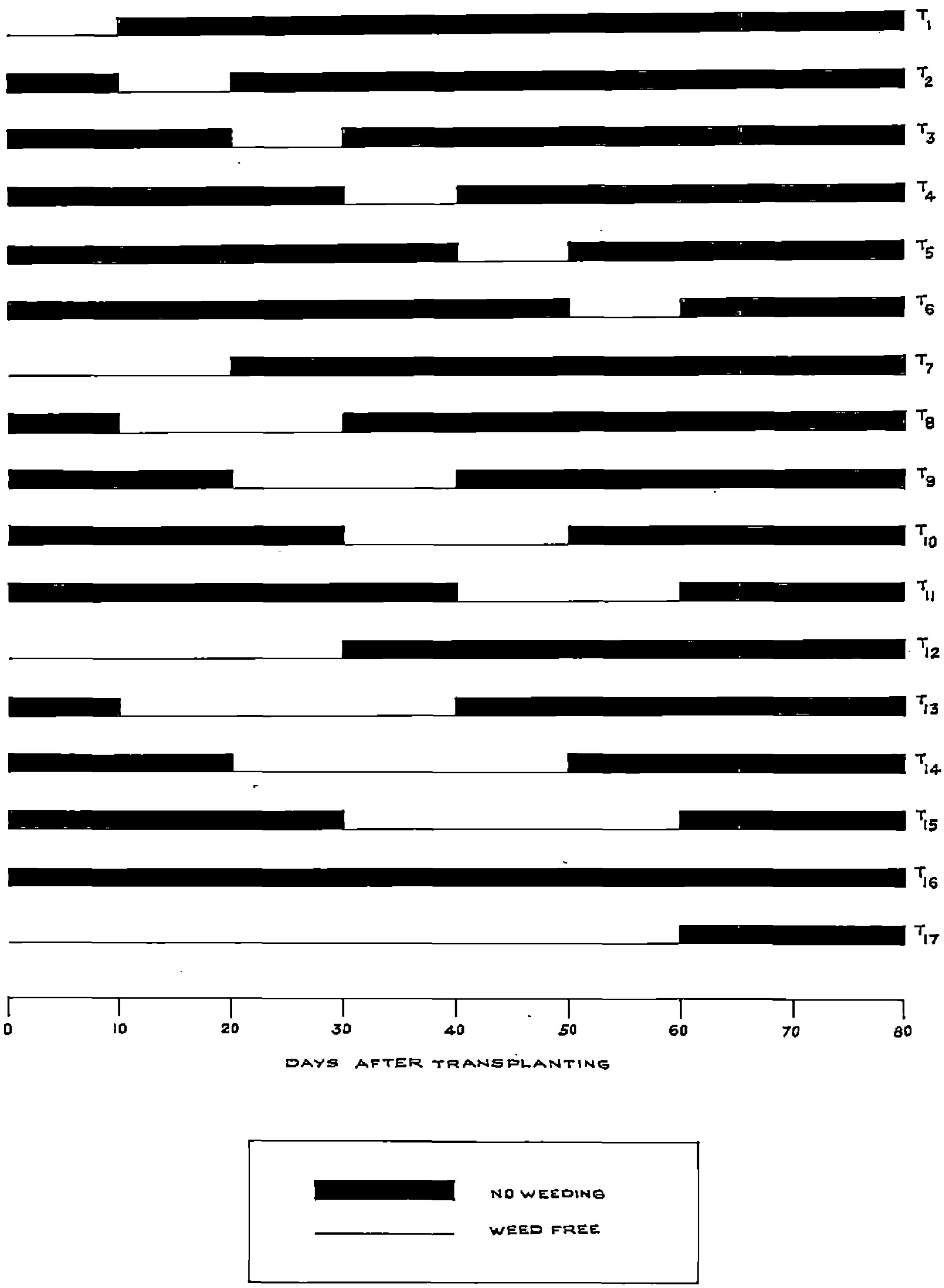


FIG. 3. DIAGRAMATIC REPRESENTATION OF DIFFERENT TREATMENTS.

Nursery

Twelve kilogramme of *Triveni* seeds were sown to get sufficient number of healthy seedlings in an area of $125m^2$. A basal dressing with 125 kg. cowdung was given. Well sprouted seeds were sown on the nursery beds on 21-10-1976.

Growth performance in the nursery

Germination was completed within 3 days. The nursery was topdressed with 3 kg. of ammonium sulphate on the 10th day after seeding. A protective spray was given with sevin at the rate of 1250 g/ha.

Main field

The experimental area was ploughed twice. Plots of 6 x 4 m size were laid out with 17 plots in each block. The plots were separated with bunds of 30 cm and blocks with bunds of 50 cm thickness. Individual plots were puddled well and perfectly levelled. Irrigation and drainage channels were provided between plots.

Fertilizer application

Ammonium sulphate, super phosphate and muriate of potash were applied to each plot so as to supply nutrients at the rate of 70 kg. N, 35 kg. P_2O_5 and K_2O per hectare respectively. Two third N and full P_2O_5 and K_2O were applied as basal at the time of last ploughing. One third of Nitrogen was applied just before panicle initiation.

Weed seeds application

Seeds of *Echinochloa crusgalli* collected 3 months before were sown at the time of transplanting just before final levelling at the rate of 5 g. per plot.

Transplanting:

Seedlings were uprooted and transplanted in the main field 20 days after sowing (10-11-1976) with 2 seedlings per hill in lines at 15 x 10 cm spacing.

Irrigation and drainage

After transplanting controlled irrigation and drainage were given as and when required.

Plant protection

Two protective sprayings with ekalux on 25th day after transplanting and metacid and hinosan on 45th day after transplanting were given.

General stand of the crop

The general stand of the crop was good. There was no lodging or severe attack of pests and diseases. The third replication was destroyed by flood, and so had to be eliminated.

Harvest

The crop was harvested on 30-1-1977, eighty days after transplanting.

Observations

An area of 1.2 x 4 m on one side of the 6 x 4 m plot was used to take observations on weeds on 10th, 20th, 30th, 40th, 50th and 60th day of after transplanting. At harvest weed count were taken from the net plot. All observations were made from separate areas from an area occupied by 6 x 6 hills (0.54 m^2) leaving border rows.

Three 2 x 2 hills sampling units per plot giving a total of 12 hills for tiller count and 3 hills for plant height, were selected randomly after eliminating the guard rows. (Gomez, 1972). Observations on leaf area index were made from the weed observation plots on 20th, 30th, 40th, 50th and 60th days after transplanting.

1. Observations on weeds

A. Weed species

The different species of weeds belonging to grasses, sedges and broadleafed weeds were collected and identified from the experimental area before and during the experiment.

B. Weed count

Weed samples were collected on 10th, 20th, 30th, 40th, 50th and 60th day after transplanting and at harvest, from an area of 0.54 m^2, which was occupied by 36 hills of rice and expressed in number/m^2. Monocot and dicot weed populations were also recorded. The weeds were pulled out carefully without damage, washed, identified and dried under shade.

C. Dry matter of weeds

Dry weight of weeds collected at each time were recorded. The total dry matter production by weeds for each treatment was worked out by adding the dry weight of weeds, recorded on the day just before the commencement of weeding and the dry weight at harvest.

II. Crop Growth Characters

a. Height of plant

The plant height in cms were recorded on 10th, 20th, 30th, 40th, 50th and 60th days after transplanting and at harvest. Height of plants were measured from the bottom to the tip of the longest leaf or the tip of the earhead whichever was tallest.

b. Number of tillers per square metre

The tillers from each sampling unit were counted on 20th, 30th and 40th day after transplanting and at harvest and values per squares metre were computed.

c. Leaf area index

Leaf area index were recorded on 20th, 30th, 40th, 50th and 60th day after transplanting.

'n' sample hills (usually 7 Nos.) were selected each time. The maximum width (w) and length (l) of all the leaves of the middle tillers were noted and leaf area per tiller was worked out using the formula.

Leaf area = k x l x w, where k is an adjustment factor = 0.75.

Leaf area per hill = Total leaf area of middle tiller x total number of tillers.

$$\text{Leaf area index} = \frac{\text{Sum of leaf area/hill of 'n' sample hills } (cm^2)}{\text{Area of land covered by 'n' hills}}$$

III. Yield Characters

a. Productive tillers per square metre

Number of productive tillers from each sampling unit were counted and the value per square metre computed.

b. Percentage of productive tillers

Number of productive tillers from each sampling unit were counted and the percentage worked out on the total number of tillers at maximum tillering stage.

c. Length of panicle

Length in cms from the neck to the tip of the sample panicles were measured.

d. Weight of panicle

The average weight of a panicle was determined and expressed in g.

e. Number of spikelets per panicle

The total number of filled and unfilled grains of all the sample panicles were recorded and the average worked out.

f. Number of filled grains per panicle

The total number of filled grains of all the sample panicles were recorded and the average worked out.

g. Percentage of filled grains per panicle

Completely filled and unfilled grains in each panicle were separately recorded and the percentage of filled grains calculated.

h. Thousand grain weight

One thousand grain were counted from the winnowed and cleaned produce from each plot, weighed and recorded in g.

i. Grain yield

The grain harvested from each net plot was dried, cleaned, winnowed and weighed. From this, yield of grain in kg./ha was computed.

j. Straw yield

The straw was cleaned by separating weeds and dried in sun. The weight of sun dried straw was recorded plot-wise and from this, the yield of straw in kg/ha was computed.

k. Weed index

Weed index was computed following the formula suggested by Gill and Vijayakumar (1969)

$$WI = \frac{X - Y \times 100}{X}$$

WI = Weed index

X = Yield from weed free plot or the treatment which recorded minimum weeds

Y = Yield from the treatment for which weed index is to be worked out.

IV. Chemical Analysis

A. Soil analysis

Composite soil sample collected prior to the commencement of the experiment, was analysed to determine the physical composition, total nitrogen, available P_2O_5 and available K_2O. The pH of the soil was determined using a pH meter in a 1: 2 soil solution.

B. Plant analysis

The N, P_2O_5 and K_2O content of weed samples were estimated on 20th, 30th, 40th, 50th and 60th day after transplanting. At harvest N, P_2O_5 and K_2O content of both crop and weeds were estimated. Grain and straw were separately analysed. The total N, P_2O_5 and K_2O uptake by weeds for each treatment was worked out by adding the N, P_2O_5 and K_2O uptake by weeds before weeding and at harvest respectively. The nutrient uptake by weed and crop (N, P_2O_5 and K_2O) in kg/ha were also worked out for all the estimations.

a. Total nitrogen.

The total nitrogen content was estimated colorimetrically after sulphuric acid digestion by the method suggested by Poiduveri and Robinson (1965).

b. Total phosphorous.

The total P_2O_5 content was estimated colorimetrically in the sulphuric acid digest for N, using amino-napthal sulfonic acid as reducing agent according to the method suggested by Jackson (1967). The colour was read using a 'spectronic 20', spectro photometer at wavelength 660 m μ.

c. Total potassium.

The total K_2O content was also estimated in the sulphuric acid digest with necessary dilution using a EEL flame photometer.

d. Protein content of grain.

The protein content of grains was computed by multiplying the N content of the whole grain by a factor 6.25 (Simpson et al. 1965).

V. Statistical Analysis

The data were analysed statistically following the methods of Snedecor and Cochran (1967). 'F' test was carried out by analysis of variance method and significant results were compared by working out the critical differences. The data on weed population, percentage of productive tillers, percentage of filled grains were analysed only after transformation. Important correlations were also worked out.

RESULTS

R E S U L T S

The biometric observations were statistically analysed and the analysis of variance tables are presented in Appendix II to XI. The summary tables are given in Table 2 to 13.

I. Observations on Weeds

A. Weed Species

The different species of weeds found in the experimental area were collected and identified before and during the experiment. They were grouped into grasses, sedges and broad-leafed weeds and presented in Table 1. *Echinochloa crusgalli*, *Brachiaria ramosa*, *Ischaemum rugosum*, *Fimbristylis milliacea*, *Cyperus* spp., *Monochoria vaginalis* and *Ludwigia parviflora* were the predominant weed species.

B. Weed Count

Observations on monocot, dicot and total number of weeds were recorded at 10 days intervals upto 60th day after transplanting and once at harvest. All counts were made from an area occupied by 6 hills x 6 hills of rice (0.54m^2) and expressed in number per square metre. Mean values of weedy check (T_{16}) are presented in Table 3 b.

Table I.

List of weeds found in the experimental field.

Scientific name	Family
I. Grasses:	
1. *Brachiaria ramosa*	Gramineae
2. *Ischaemum rugosum*	Gramineae
3. *Echinochloa crus-galli*	Gramineae
4. *Echinochloa colonum*	Gramineae
5. *Oryza sativa* var. fatua	Gramineae
6. *Paspalum* spp.	Gramineae
II. Sedges:	
1. *Fimbristylis miliacea*	Cyperaceae
2. *Cyperus iria*	Cyperaceae
3. *Cyperus rotundus*	Cyperaceae
4. *Cyperus difformis*	Cyperaceae
5. *Scirpus articulatus*	Cyperaceae
III. Broad-leafed weeds:	
1. *Monochoria vaginalis*	Pontederiaceae
2. *Ludwigia parviflora*	Onagraceae
3. *Marsilea quadrifolia*	Marsileaceae
4. *Limnophila heterophylla*	Scrophulariaceae
5. *Oldenlandia corymbosa*	Rubiaceae

From the data, observations on number of monocot weeds, dicot weeds and total weeds/m^2, immediately before weeding, 10 days after weeding and at harvest were analysed after transforming by using square root transformation, $\sqrt{x+1}$ where, 'x' is the number of weeds. In the case of weed counts before weeding, observations were available only from 12 plots per block since treatments 1, 7, 12, 16 and 17 had to be eliminated. Similarly for counts of weeds 10 days after weeding observations were available only from 12 plots per block since treatments 6, 11, 15, 16 and 17 had to be eliminated.

1. Monocot weed population/m^2.

The analysis of variance tables are presented in Appendix II and the mean values in Table 2 a.

a. Pre-weeding.

Monocot weed population on 50th day (T_6) was maximum ($16.90/m^2$) and was on par with weed counts on 40th day (T_5 and T_{11}). Monocot weed counts on 30th day, in T_{15} was on par with T_{10} which in turn was on par with T_4. Monocot weed counts on 30th day were significantly lesser than counts upto 50th and 40th day and significantly higher than counts upto 20th day (T_3, T_{14} and T_9). On the 10th day (T_2, T_8 and T_{13}) since the weeds did not appear the counts were considered as zero and was not on par with count on 20th day.

b. 10 days after weeding.

Monocot weed emergence 10 days after weeding, during 31-40 was maximum (7.07/m^2) in T_{12} (weeded 1-30 days) and was on par with weed emergence during 31-40 in T_3 and T_8, 21-30 in T_2 and T_7 and 11-20 in T_1 and were significantly higher than emergence during 41-50 and 51-60 days.

Monocot weed emergence during 41-50 (T_4, T_9 and T_{13}) and that during 51-60 (T_5, T_{10} and T_{14}) were on par and formed the lowest level (3.73 - 4.40/m^2).

c. At harvest.

Monocot weed count at harvest in weedy check (T_{16}) was the highest (20.13/m^2) and was on par with very early weeded plot T_1 (weeded 1 - 10 days). Plots weeded upto 20th day (T_2 and T_7) were on par and were significantly lesser than T_{16} and T_1 and significantly higher than plots weeded upto 30th, 40th, 50th and 60th day, after transplanting. Treatments T_8, T_3 and T_{12} (weeded upto 30th) were on par and were significantly higher than plots weeded upto 40th, 50th and 60th day.

Plots weeded upto 60th day (T_{17}, T_{15}, T_{11} and T_6) were on par and had the lowest level of monocot weed count at harvest (3-4/m^2) followed by plots weeded upto 50th day (T_{10},

Table 2a

Monocot weed population/m^2
(After square root transformation)

Treatments (Weed free D.A.T)		Pre-weeding	10 days post weeding	At harvest
T_1	1-10	..	6.63(43.0)	18.55(344.0)
T_2	11-20	1.00(0.0)	6.86(46.0)	15.90(253.0)
T_3	21-30	6.29(38.6)	6.42(40.2)	9.89(96.8)
T_4	31-40	9.62(91.6)	4.40(18.4)	5.91(33.7)
T_5	41-50	16.43(269.0)	4.24(17.0)	5.12(25.2)
T_6	51-60	16.90(285.0)	..	4.00(15.0)
T_7	1-20	..	6.32(39.0)	15.25(232.0)
T_8	11-30	1.00(0.0)	6.32(39.0)	9.95(98.0)
T_9	21-40	7.49(55.1)	4.37(18.1)	6.67(43.5)
T_{10}	31-50	11.53(131.0)	3.82(13.6)	4.74(21.5)
T_{11}	41-60	16.13(259.0)	..	3.16(9.0)
T_{12}	1-30	..	7.07(49.0)	9.56(90.0)
T_{13}	11-40	1.00 (0.0)	3.45(10.9)	6.16(37.0)
T_{14}	21-50	7.03(48.4)	3.73(12.9)	5.00(24.0)
T_{15}	31-60	12.88(164.0)	..	3.00(8.0)
T_{16}	Weedy check	..	..	20.13(405.0)
T_{17}	1-60	..	..	3.00(8.0)
CD (0.05)		1.754	1.488	1.715

Note: Data in brackets are the number of weeds/m^2

T_{14} and T_5) and plots weeded upto 40th day. (T_4, T_{13} and T_9).

Among the 10, 20 and 30 day weed free periods tried, treatments T_4 (weeded 31-40), T_8 (weeded 11-30) and T_9 (weeded 21-40) and T_{13} (weeded 11-40) recorded the minimum monocot weeds, considering the total number of monocot weeds just before weeding and at harvest.

The rate of increase in monocot weed population in weedy check (T_{16}) were 16.50, 8.64, 36.45, 11.33, 22.42 and 4.68 per cents, during 11-20, 21-30, 31-40, 41-50, 51-60 days and 61 to harvest (80th day) respectively.

2. Dicot weed population/m^2

The analysis of variance tables are presented in Appendix II and the mean values in Table 2 b.

a. Pre-weeding

Dicot weed population was maximum ($19.13/m^2$) on 50th day in T_6 and was on par with weed counts on 40th day in T_{11} and T_5.

Dicot weed counts on 30th day in T_{10} was on par with T_{15} which in turn was on par with T_4. Weed counts upto 30th day (T_{10}, T_{15} and T_4) were significantly lower than the weed count on 50th day in T_6 and 40th day in T_{11} and significantly higher than weed counts on 20th day in T_{14}, T_3 and T_9. Counts on 20th and 10th were significantly different. Since the weed appearance was not noted on the 10th day (T_2, T_8 and T_{13}) the counts were considered as zero.

b. 10 days after weeding

Dicot weed emergence 10 days after weeding, during 11-20 (T_1) was the maximum ($9.37/m^2$) and was on par with weed emergence during 21-30 days. (T_2 and T_7). Weed emergence during 31-40 days (T_8, T_3 and T_{12}) were significantly lesser than emergence during 11-20 and 21-30 and greater than those during 41-50 and 51-60 days after transplanting. Dicot weed emergence during 41-50 days (T_9, T_{13} and T_4) and 51-60 days (T_5, T_{10} and T_{14}) formed the lowest level. (2.91-$3.74/m^2$).

c. At harvest

Dicot weed population at harvest was maximum ($17.70/m^2$) in weedy check (T_{16}) followed by those in plots weeded early ie. 1-10 (T_1), 1-20 (T_7), 11-20 (T_2) and 21-30 (T_3) days after transplanting. Plots weeded upto 30th day (T_{12} and T_8) were on par with T_{13} (weeded 11-40 days) and were superior to plots weeded upto 40th (T_9 and T_4), 50th and 60th day after transplanting.

Table 2b

Dicot weed population/m^2
(After square root transformation)

Treatments (weed free D.A.T.)		Pre-weeding	10 days post weeding.	At harvest
T_1	1-10	..	9.37(86.8)	14.63(213.0)
T_2	11-20	1.00(0.0)	9.25(84.6)	11.05(122.0)
T_3	21-30	10.33(105.0)	5.50(29.2)	7.05(48.7)
T_4	31-40	14.15(200.0)	3.16(9.0)	4.69(21.0)
T_5	41-50	17.83(317.0)	3.15(9.0)	4.16(16.1)
T_6	51-60	19.13(365.0)	..	3.00(8.0)
T_7	1-20	..	9.19(83.4)	12.43(153.0)
T_8	11-30	1.00(0.0)	5.70(31.5)	6.08(36.0)
T_9	21-40	9.74(93.8)	3.74(13.0)	5.12(25.2)
T_{10}	31-50	16.33(265.0)	3.15(9.0)	4.12(16.0)
T_{11}	41-60	18.18(328.0)	..	3.16(9.0)
T_{12}	1-30	..	4.90(23.0)	6.24(37.9)
T_{13}	11-40	1.00(0.0)	3.58(11.8)	5.61(30.5)
T_{14}	21-50	11.20(125.0)	2.91(7.5)	4.11(15.9)
T_{15}	31-60	14.88(220.0)	..	3.00(8.0)
T_{16}	Weedy check	..	..	17.70(313.0)
T_{17}	1-60	..	..	2.83(7.0)
	CD (0.05)	1.616	0.951	0.740

Note: Data in brackets are the weed number/m^2

The lowest level of dicot weed count at harvest ($2.83-3.16/m^2$) were in plots weeded upto 60th day (T_{17}, T_{15}, T_6 and T_{11}) followed by those plots weeded upto 50th day (T_{14}, T_{10} and T_5) after transplanting.

Considering the total number of dicot weeds just before weeding and those re-established till harvest, plots weeded 11-20 (T_2), 11-30 (T_8) and 11-40 (T_{13}) days recorded the minimum weeds among the 10,20 and 30 day intervals of weed free treatments, respectively.

The rate of dicot weed increase in weedy check (T_{16}) showed that it reached a maximum of $372/m^2$ by 40th day and thereafter it decreased. The pattern of increase were 29.83, 43.28 and 26.89 per cents during 11-20, 21-30 and 31-40 days after transplanting respectively.

3. Total weed population/m^2

The analysis of variance tables are presented in Appendix II and the mean values in Table 2c.

a. Pre-weeding

Total weeds on 50th day (T_6) was the highest ($23.50/m^2$) and was on par with weed counts on 40th day in T_{11} and T_5. Weed counts on 30th day in T_{10} and T_{15} were the next higher count followed by that in T_4. Weed counts upto 30th day were significantly lesser than counts upto 50th and 40th days and significantly higher than the counts upto 20th (T_{14}, T_3 and T_9) day after transplanting. Since the weed appearance was not noted on the 10th day after transplanting (T_2, T_8 and T_{13}), counts were taken as zero and was significantly different from counts on 20th day.

b. 10 Days after weeding

Total weed emergence, during 10 days after weeding was maximum in T_2 (11.50/m^2) and was on par with that in T_1 and T_7. Total weed emergence during 31-40 days (T_{12}, T_8 and T_3) were significantly lesser than the emergence during 11-20 and 21-30 and greater than the emergence during 41-50 and 51-60 days.

Emergence during 41-50 days (T_9, T_4 and T_{13}) and 51-60 days (T_5, T_{10} and T_{14}) were on par and formed the lowest level (4.62 - 5.68/m^2)

c. At harvest.

Maximum weed population (26.80/m^2) was in weedy check (T_{16}) at harvest and was significantly greater then early weeded plot (T_1) (weeded 1-10 days). Plots weeded upto 20th day (T_7 and T_2) were significantly lesser than weedy check and T_1 and higher than plots weeded upto 30th, 40th, 50th and 60th day after transplanting.

Table 2c

Total weed population/M^2
(After square root transformation)

Treatments (Weed free D.A.T.)		Pre-weeding	10 days post weeding.	At harvest
T_1	1-10	..	11.43(129.0)	23.68(558.0)
T_2	11-20	1.00(0.0)	11.50(131.0)	19.35(374.0)
T_3	21-30	12.08(144.0)	8.40(69.6)	12.13(145.0)
T_4	31-40	17.08(290.0)	5.37(27.8)	7.52(55.6)
T_5	41-50	24.20(586.0)	5.20(26.0)	6.43(40.4)
T_6	51-60	25.50(651.0)	..	4.90(23.0)
T_7	1-20	..	11.13(123.0)	19.63(385.0)
T_8	11-30	1.00(0.0)	8.45(70.4)	11.65(134.0)
T_9	21-40	12.03(143.0)	5.68(31.3)	8.39(69.4)
T_{10}	31-50	19.98(398.0)	4.91(23.1)	6.16(37.0)
T_{11}	41-60	24.28(588.0)	..	4.35(17.9)
T_{12}	1-30	..	8.55(72.1)	11.38(128.0)
T_{13}	11-40	1.00(0.0)	4.93(23.3)	8.31(68.0)
T_{14}	21-50	13.03(169.0)	4.62(20.3)	6.39(39.8)
T_{15}	31-60	19.65(386.0)	..	4.12(16.0)
T_{16}	Weedy check	..	..	26.80(719.0)
T_{17}	1-60	..	..	4.00(15.0)
	CD (0.05)	1.673	1.591	1.830

Note: Figures in brackets are the weed number/m^2

Plots weeded upto 60th day (T_{17}, T_{15}, T_{11} and T_6) had the lowest weed population at harvest (4.00 - 4.90/m^2) followed by plots weeded upto 50th day (T_{10}, T_{14} and T_5), 40th day (T_4, T_{13} and T_9) and 30th day (T_3, T_8 and T_{12}) after transplanting.

Considering the weed population just before weeding and at harvest together, the minimum weed population of 289 weeds/m^2 was recorded in T_3 (weeded 21-30 days) among the plots weeded at 10 day intervals; 134 weeds/m^2 in T_8 (weeded 11-30 days) among the 20 day intervals and 68 weeds/m^2 in T_{13} (weeded 11-40 days) among the 30th day intervals weed free treatments.

The rate of increase in total weeds in weedy check (T_{16}) continued upto 60th day (720 weeds/m^2) after which it got levelled off. The rate of increase were 24.85, 27.22, 34.04, 5.30 and 8.59 per cents during 11-20, 21-30, 31-40, 41-50 and 51-60 days respectively.

In weedy check (T_{16}) monocots and dicots were 37.65 and 62.35 per cent of the total weeds during the early stages and were 56.47 and 43.53 per cent at harvest. The monocot weed emergence in weedy check continued upto harvest whereas the dicot weed emergence reached maximum on 40th day and thereafter it decreased in number.

Post weeding emergence of monocot weeds 10 days after weeding were maximum during 31-40 days, followed by 21-30 and 11-20 days, whereas the post weeding dicot weed emergence was maximum during 11-20 days followed by 21-30 and 31-40 days.

C. Dry matter production by weeds g/m^2

The data on dry matter before weeding, at harvest and total dry matter (before weeding + at harvest) were analysed separately and the analysis of variance tables are presented in Appendix III and the mean values in Table 3a and the pattern of dry matter accumulation in weedy check (T_{16}) is presented in Table 3 b. Data on pre-weeding dry matter were available only from 12 plots since treatments 1, 7, 12, 16 and 17 had to be eliminated.

a. Pre-weeding

Dry matter accumulation by weeds upto 50th day in T_6 was the maximum (105.19 g/m^2) and was on par with dry matter accumulation upto 40th day (T_{11} and T_5). Dry matter accumulation upto 30th day (T_{10}, T_{15} and T_4) were significantly lesser than accumulation upto 40th day and 50th day and significantly higher than accumulation upto 20th day (T_{14}, T_9 and T_3). Accumulation upto 20th formed the lowest level (3.85-6.20 g/m^2) and were on par with plots having zero dry matter(T_2, T_8 and T_{13}).

b. At harvest

Unweeded check (T_{16}) had the maximum dry matter accumulation (154.18 g/m^2) which was superior to all other treatments. Dry matter accumulation in plots weeded very early ie. 1-10 days (T_1) was significantly lesser than weedy check and was superior to all other treatments. Plots weeded upto 20th day (T_7 and T_2) were on par and were significantly greater than all the others. Plots weeded upto 30th (T_3, T_8 and T_{12}) were on par with plots weeded upto 40th (T_{13}, T_9 and T_4) and was the next higher level of dry matter accumulation.

Plots weeded upto 50th (T_5, T_{10} and T_{14}) and 60th day (T_6, T_{15}, T_{11} and T_{17}) were on par and had the lowest level of dry matter accumulation at harvest (2.00-7.37 g/m^2).

c. Total

Unweeded check T_{16} recorded the maximum total dry matter of 154.18 g/m^2 and was on par with early weeded plot T_1 (weeded 1-10 days). Plots weeded 51-60 (T_6), 41-50 (T_5) and 41-60 (T_{11}) days were on par and were significantly lesser than T_{16} and T_1. Plots weeded 1-20 (T_7) and 11-20 (T_2) days recorded the next higher level of dry matter production and were on par with T_5 and T_{11} and were significantly lesser than T_{16} and T_1. Treatment T_2 was significantly lesser than

Table 3a
Dry weight of weeds (g/m^2)

Treatments (Weed free D.A.T.)		Pre-weeding	At harvest	Total
T_1	1-10	-	137.05	137.05
T_2	11-20	0	72.69	72.69
T_3	21-30	3.85	24.05	27.90
T_4	31-40	26.32	15.18	41.50
T_5	41-50	85.86	7.37	93.23
T_6	51-60	105.19	5.65	110.84
T_7	1-20	-	81.27	81.27
T_8	11-30	0	22.22	22.22
T_9	21-40	4.07	15.83	19.90
T_{10}	31-50	33.76	5.52	39.28
T_{11}	41-60	85.90	3.57	89.47
T_{12}	1-30	-	21.20	21.20
T_{13}	11-40	0	16.67	16.67
T_{14}	21-50	6.20	6.58	12.78
T_{15}	31-60	32.56	4.17	36.73
T_{16}	Weedy Check	-	154.18	154.18
T_{17}	1-60	-	2.00	2.00
	CD (0.05)	20.094	13.191	22.195

Table 3b

Pattern of weed growth in weedy check (T_{16})

Number of days after transplanting.	Weed population/m²				Total weeds	Dry weight of weeds (g/m²)
	Monocots		Dicots			
	Number/m²	% of total population.	Number/m²	% of total population.		
20th	65	37.65	111	62.35	178	7.19
30th	102	27.28	272	72.72	374	30.98
40th	250	40.00	372	60.00	622	88.43
50th	296	44.62	365	55.38	661	108.81
60th	387	53.75	333	46.25	720	129.27
At harvest (80th)	406	56.47	313	43.53	719	154.18

T_6 (weeded 51-60) also.

Treatments T_{17}, T_{14}, T_{13}, T_9, T_{12} and T_8 recorded the lowest dry matter ranging from 2.00-22.22 g/m^2. Treatments T_9, T_{12} and T_8 were in turn on par with T_3, T_{15}, T_{10} and T_4.

Among the plots weeded 10, 20 and 30 day intervals the least weed dry matter accumulation were in plots weeded 21-30 (27.90 g/m^2) 21-40 (19.90 g/m^2) and 21-50 (12.78 g/m^2) days after transplanting respectively.

The dry matter accumulation by weeds in weedy check (T_{16}) continued upto harvest, the percentage of increase were 4.66, 15.43, 37.27, 13.21, 13.27 and 16.16 during 11-20, 21-30, 31-40, 41-50, 51-60 and 61 to harvest (80th day) respectively.

II. Crop Growth Characters

a. <u>Height of plants</u>

The observations on height of plants were recorded on 10th, 20th, 30th, 40th, 50th and 60th day after transplanting and at harvest. The data were analysed separately and the analysis of variance tables are presented in Appendix IV and the mean values is Table 4.

Plant height did not show any significant difference among the different periods of weed free condition and the weedy check, at different stages of crop growth, but the weed free plots recorded higher plant height than weedy plots by 50th and 60th day after transplanting.

b. Tiller number per square metre.

The observations on tiller number were taken on 10th, 20th, 30th and 40th day after transplanting and at harvest. The analysis of variance tables are presented in Appendix V and the mean values in Table 5.

Tiller number/m^2 did not show any significant difference, at all the stages of growth, with weeding periods.

c. Leaf area index.

Observations on leaf area index were made on 20th, 30th, 40th, 50th and 60th day after transplanting. The analysis of variance tables are presented in Appendix VI and the mean values in Table 6. Leaf area index was not significant during any stage of crop growth.

III. Yield Characters

a. Productive tillers per square metre.

The analysis of variance table is presented in Appendix VII and the mean values in Table 7.

The plot which was kept weed free 11 - 20 days (T_2) recorded the maximum number of productive tillers (331.5/m^2)

Table 4.

Height of plants (cm)

Treatments (Weed free days after transplanting)		Number of days after transplanting						
		10	20	30	40	50	60	At harvest
T_1	1-10	25.83	40.50	52.67	58.33	61.66	68.00	68.84
T_2	11-20	26.33	42.50	52.33	53.00	60.33	70.00	71.17
T_3	21-30	26.00	41.16	53.16	55.16	61.33	71.00	70.34
T_4	31-40	26.33	39.67	49.16	53.00	64.17	67.66	70.34
T_5	41-50	30.00	39.33	53.16	55.00	56.16	67.66	67.50
T_6	51-60	30.00	42.00	52.50	53.83	58.50	67.60	67.33
T_7	1-20	23.33	39.17	53.50	53.16	59.83	70.33	67.67
T_8	11-30	30.33	41.00	53.17	56.83	63.66	71.83	71.17
T_9	21-40	28.67	40.00	53.00	54.67	62.33	71.33	69.17
T_{10}	31-50	28.00	40.17	49.67	54.50	58.66	70.50	69.50
T_{11}	41-60	26.16	37.17	48.50	51.17	55.33	67.00	64.00
T_{12}	1-30	31.83	42.17	57.17	59.17	65.00	73.66	70.67
T_{13}	11-40	25.67	39.33	53.33	53.50	60.33	70.83	70.62
T_{14}	21-50	29.33	39.00	56.83	58.33	65.50	74.00	73.50
T_{15}	31-60	26.50	37.16	53.16	53.66	59.33	72.50	67.50
T_{16}	(Weedy check)	26.16	39.33	54.00	55.33	56.33	67.83	66.50
T_{17}	1-60	27.50	39.83	53.16	57.17	58.16	73.33	71.34

Table 5

Number of tillers /m^2

Treatments (Weed free days after transplanting)		Number of days after transplanting				
		10	20	30	40	At harvest
T_1	1-10	220.4	361.8	358.5	363.1	276.7
T_2	11-20	268.0	459.0	502.5	443.5	374.5
T_3	21-30	209.0	358.5	415.4	413.4	324.3
T_4	31-40	251.3	398.7	428.8	412.1	324.3
T_5	41-50	237.2	395.3	435.5	407.4	290.8
T_6	51-60	209.0	358.5	438.9	391.3	320.9
T_7	1-20	217.8	358.5	445.6	404.7	365.8
T_8	11-30	212.4	321.6	405.4	399.3	330.3
T_9	21-40	215.8	381.9	452.3	452.9	346.4
T_{10}	31-50	225.8	392.0	418.8	376.5	318.3
T_{11}	41-60	223.1	392.0	472.4	402.7	310.2
T_{12}	1-30	203.7	328.3	378.6	367.2	346.4
T_{13}	11-40	223.1	351.8	425.5	435.5	349.1
T_{14}	21-50	206.4	371.9	392.0	365.8	315.6
T_{15}	31-60	211.7	375.2	398.7	391.3	318.3
T_{16}	(Weedy check)	217.8	365.2	361.8	346.4	304.2
T_{17}	1-60	206.4	308.2	381.9	377.2	314.2

Table 6

Leaf area index

Treatments (Weed free days after transplanting)		Number of days after transplanting 20	30	40	50	60
T_1	1-10	2.35	4.30	5.81	4.23	4.89
T_2	11-20	2.52	4.48	5.46	4.99	4.37
T_3	21-30	3.23	5.44	5.99	5.15	3.89
T_4	31-40	2.00	5.20	5.04	4.66	4.10
T_5	41-50	2.95	5.72	5.81	5.20	3.41
T_6	51-60	2.43	4.72	5.30	5.04	4.56
T_7	1-20	2.27	5.29	5.83	5.59	4.50
T_8	11-30	2.45	4.27	4.53	4.84	4.00
T_9	21-40	2.31	4.43	5.21	5.41	4.05
T_{10}	31-50	2.74	4.65	5.13	4.85	3.97
T_{11}	41-60	2.63	4.73	5.42	4.93	4.56
T_{12}	1-30	2.22	5.64	4.78	4.77	3.90
T_{13}	11-40	2.92	5.26	4.79	4.70	4.11
T_{14}	21-50	2.32	4.98	4.74	4.26	3.77
T_{15}	31-60	2.71	4.71	4.50	4.73	3.85
T_{16}	(Weedy check)	2.82	4.45	5.49	4.44	3.73
T_{17}	1-60	2.77	4.86	5.15	5.76	4.32

which was on par with plots weeded 1-20 (T_7), 21-40 (T_9), 31-40 (T_4), 11-30 (T_8), 1-60 (T_{17}), 11-40 (T_{13}), 31-50 (T_{10}), 21-30 (T_3) and 1-30 (T_{12}) days after transplanting. Plot weeded 1-10 days (T_1) recorded the least number of productive tillers (207.5/m^2) and was on par with unweeded check (T_{16}) and plots weeded 51-60 (T_6), 41-50 (T_5), 31-60 (T_{15}) and 41-60 (T_{11}) days after transplanting. Treatment T_{14} was on par with T_{17}, T_{13}, T_{10}, T_3 and T_{12} of higher tiller group and T_{16}, T_6, T_5, T_{15} and T_{11} of lower tiller groups.

b. Percentage of productive tillers

Data on percentage of productive tillers were analysed after transforming using angular transformation. The analysis of variance table is presented in Appendix VII and the mean values in Table 7.

The highest percentage of productive tillers (62.07) was recorded in plot weeded 1-60 days after transplanting (T_{17}) and was on par with plots weeded 11-30 (T_8), 1-30 (T_{12}), 21-40 (T_9), 1-20 (T_7), 31-50 (T_{10}), 31-40 (T_4), 11-40 (T_{13}), 21-30 (T_3), 21-50 (T_{14}) and 11-20 (T_2) days after transplanting. Plot weeded 41-60 days (T_{11}) after transplanting, had the least percentage of productive tillers (46.98) and was on par with plots weeded 51-60 (T_6), 41-50 (T_5), 1-10 (T_1) weedy check (T_{16}) and plots weeded 31-60

Table 7.

Productive tillers/m^2 and percentage productive tillers.

Treatments (Weed free days after transplanting)		Productive tillers/m^2	Percentage of productive tillers
T_1	1-10	207.5	50.54 (59.61)
T_2	11-20	331.5	54.61 (66.40)
T_3	21-30	281.5	55.91 (68.49)
T_4	31-40	301.5	56.93 (70.19)
T_5	41-50	244.5	48.59 (56.24)
T_6	51-60	238.0	47.23 (53.89)
T_7	1-20	311.5	57.09 (70.40)
T_8	11-30	298.5	59.02 (73.44)
T_9	21-40	311.5	57.15 (70.17)
T_{10}	31-50	284.5	57.07 (69.83)
T_{11}	41-60	251.0	46.98 (53.43)
T_{12}	1-30	278.0	58.97 (73.43)
T_{13}	11-40	295.0	56.42 (69.37)
T_{14}	21-50	261.5	55.52 (67.01)
T_{15}	31-60	248.0	52.20 (62.40)
T_{16}	Weedy check	221.0	51.45 (61.13)
T_{17}	1-60	296.0	62.07 (78.04)
	CD (0.05)	53.64	8.098

Note: Data on percentage of productive tillers analysed after angular transformation, and figures in brackets are the original data.

(T_{15}) and 11-20 (T_2) days after transplanting.

c. Length of panicle

The analysis of variance table is presented in Appendix VIII and the mean values in Table 8.

Length of panicle was not significant. The weedy check (T_{16}) recorded the least length of 16.99 cm and the maximum length of 19.65 cm. was recorded in treatment T_4 (weeded 31-40 days) and T_6 (weeded 51-60 days).

d. Weight of panicle

The analysis of variance table is presented in Appendix VIII and the mean values in Table 8. Plot weeded 31-50 (T_{10}) had maximum weight of panicle (1.71 g) and was on par with plots weeded 11-40 (T_{13}), 21-50 (T_{14}), 31-60 (T_{15}), 1-60 (T_{17}), 21-40 (T_9), 11-30 (T_8), 31-40 (T_4), 1-30 (T_{12}) and 21-30 (T_3) days after transplanting. Unweeded check (T_{16}) recorded the lowest weight of panicle (1.10 g) and was on par with plots weeded 1-10 (T_1), 1-20 (T_7), 51-60 (T_6), 41-50 (T_5), 11-20 (T_2) and 41-60 (T_{11}) days after transplanting.

e. Number of spiklets per panicle

The analysis of variance table is presented in Appendix VIII and the mean values in Table 8.

The spikelet number per panicle was significant. The maximum number of spikelets per panicle (80) was recorded in T_{14} (weeded 21-50 days and was on par with plots weeded, 31-50 (T_{10}), 31-40 (T_4), 31-60 (T_{15}), 1-60 (T_{17}), 11-40 (T_{13}), 11-30 (T_8), 21-40 (T_9) and 21-30(T_3) days after transplanting.

Unweeded check (T_{16}) recorded the least number of spikelets per panicle (56) and was on par with plots weeded 1-30 (T_{12}), 1-10 (T_1), 11-20 (T_2), 41-60 (T_{11}), 1-20 (T_7), 41-50 (T_5), 51-60 (T_6) 21-30 (T_3), 21-40 (T_9) and 11-30(T_8) days after transplanting.

f. Number of filled grains per panicle

The analysis of variance table is presented in Appendix VIII and the mean values in Table 8.

The effect of weed free periods was significant. Plots weeded 21-50 (T_{14}) days after transplanting recorded the maximum number of filled grains per panicle (53) and was on par with plots weeded 31-40 (T_4), 31-50 (T_{10}), 1-60 (T_{17}), 11-40 (T_{13}), 21-40 (T_9), 31-60 (T_{15}), 21-30 (T_3) and 1-30 (T_{12}) days after transplanting.

The least number of filled grains per panicle (35) was recorded in T_5 (weeded 41-50 days) and was on par with unweeded check (T_{16}) and plots weeded 41-60 (T_{11}), 11-20 (T_2)

Table 8

Panicle Characters

Treatments (Weed free days after trans-planting)		Length (cm)	Weight (g)	No. of spikelets /panicle	No. of filled grains/ panicle	Percent-age of filled grain
T_1	1-10	17.81	1.17	57	38	54.58 (66.39)
T_2	11-20	17.19	1.27	58	36	51.51 (61.25)
T_3	21-30	18.58	1.53	67	44	53.71 (64.84)
T_4	31-40	19.65	1.55	75	51	55.53 (68.04)
T_5	41-50	17.43	1.24	61	35	49.52 (57.87)
T_6	51-60	19.65	1.20	62	43	56.45 (69.36)
T_7	1-20	19.39	1.17	59	41	54.07 (70.14)
T_8	11-30	18.75	1.60	68	41	55.31 (67.58)
T_9	21-40	18.06	1.63	68	49	57.64 (71.31)
T_{10}	31-50	18.20	1.71	76	51	54.58 (66.34)
T_{11}	41-60	17.50	1.28	59	36	51.25 (60.74)
T_{12}	1-30	17.65	1.55	56	44	58.08 (71.96)
T_{13}	11-40	18.62	1.68	70	50	57.26 (70.70)
T_{14}	21-50	18.90	1.68	80	53	54.34 (65.99)
T_{15}	31-60	18.44	1.65	71	49	56.21 (69.07)
T_{16}	Weedy check	16.99	1.10	56	36	52.65 (63.14)
T_{17}	1-60	18.65	1.65	71	51	57.81 (71.32)
CD (0.05)			0.383	13.9	9.1	

Note: Data on percentage of filled grains analysed after angular transformation and figures in brackets are the original data.

1-10 (T_1), 11-30 (T_8), 1-20 (T_7) and 51-60 (T_6) days after transplanting.

g. Percentage of filled grains

Data on percentage of filled grains were analysed after transforming using angular transformation.

The analysis of the variance table is presented in Appendix VIII and the mean values in Table 8.

Percentage of fertility was not significant.

h. 1000 grain weight

The analysis of variance table is presented in Appendix IX and the mean values in Table 9. Weight per grain was not significant.

i. Grain yield

The analysis of variance table is presented in Appendix IX and the mean values in Table 9.

Plot weeded 1-60 days (T_{17}) recorded the maximum grain yield of 3466 kg/ha and was on par with weeding periods of 21-50 (T_{14}), 11-40 (T_{13}), 1-30 (T_{12}), 21-40 (T_9), 21-30 (T_3), 31-50 (T_{10}), 11-30 (T_8), 31-60 (T_{15}) and 31-40 (T_4) days after transplanting.

The unweeded check (T_{16}) recorded the lowest yield of 2533 kg/ha and was on par with plots weeded 51-60 (T_6), 1-10 (T_1) and 41-50 (T_5) days after transplanting. Plots weeded 11-20 (T_2), 41-60 (T_{11}) and 1-20 (T_7) days after transplanting were greater than weedy check and less than plot weeded 1-60 days.

j. Straw yield

The analysis of variance table is presented in Appendix IX and the mean values in Table 9.

Plots weeded 31-50 (T_{10}) and 11 - 40 (T_{13}) days recorded the maximum straw yield of 3658 kg/ha and were on par with plots weeded 1-60 (T_{17}), 21-40 (T_9), 31-40 (T_4), 1-30 (T_{12}), 31-60 (T_{15}), 21-30 (T_3), 31-40 (T_{14}) and 11-30 (T_8) days after transplanting. Plot weeded 1-20 days after transplanting (T_7) was on par with plots weeded 11-20 (T_2) and 41-60 (T_{11}). T_2 and T_{11} were in turn on par with T_5 (weeded 41-60 days). Unweeded check (T_{16}) recorded the lowest straw yield (2756 kg/ha) and was on par with plots weeded 1-10 (T_1) and 51-60 (T_6) days after transplanting.

k. Weed index

Weed index was calculated for the different weed free periods using the formula suggested by Gill and

Table 9

Yield Characters

Treatments (Weed free days after transplanting)		1000 grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)
T_1	1-10	23.95	2636	2761
T_2	11-20	23.80	2920	3153
T_3	21-30	24.35	3248	3499
T_4	31-40	24.45	3175	3611
T_5	41-50	24.62	2818	2993
T_6	51-60	24.55	2599	2828
T_7	1-20	23.90	3066	3228
T_8	11-30	24.43	3208	3423
T_9	21-40	24.10	3307	3618
T_{10}	31-50	24.14	3224	3658
T_{11}	41-60	23.40	2966	3140
T_{12}	1-30	24.72	3314	3542
T_{13}	11-40	24.60	3383	3658
T_{14}	21-50	24.05	3406	3472
T_{15}	31-60	24.17	3175	3535
T_{16}	Weedy check	23.60	2583	2756
T_{17}	1-60	25.05	3466	3631
	C.D. (0.05)		326.7	215.9

Table 10
Weed Index

Treatments (Weed free days after transplanting)		Yield (Grain + straw) (Kg/ha)	Weed Index
T_1	1-10	5397	23.95
T_2	11-20	6073	14.42
T_3	21-30	6747	4.93
T_4	31-40	6786	4.38
T_5	41-50	5811	18.12
T_6	51-60	5427	23.53
T_7	1-20	6294	11.31
T_8	11-30	6631	6.56
T_9	21-40	6925	2.42
T_{10}	31-50	6882	3.02
T_{11}	41-60	6106	13.96
T_{12}	1-30	6856	3.39
T_{13}	11-40	7041	0.78
T_{14}	21-50	6878	3.08
T_{15}	31-60	6710	5.45
T_{16}	Weedy check	5289	25.47
T_{17}	1-60	7097	0.0

Vijayakumar (1969) and presented in Table 10.

Treatment 17 (weeded 1-60 days) recorded the minimum weeds and so yield from that treatment was taken as 'X' for calculating the index. From the results it was found that unweeded check (T_{16}) had the highest weed index (25.47) followed by plot weeded 1-10 (T_1) and 51-60 (T_6) days after transplanting. Plot weeded 11-40 days (T_{13}) recorded the least weed index of 0.78.

IV. Chemical Analysis

A. Nutrient uptake by weeds

Data on nutrient uptake by weeds, before weeding at harvest and total nutrient uptake were analysed. In the case of pre-weeding nutrient uptake, data were available only from 12 plots since treatments T_1, T_7, T_{12}, T_{16} and T_{17} had to be eliminated. The pattern of uptake of N, P_2O_5 and K_2O in weedy check are presented in Table 11d.

1. Nitrogen uptake by weeds

The analysis of variance tables are presented in Appendix X and the mean values in Table 11a.

a. Pre-weeding.

Nitrogen uptake by weeds upto 50th day was the maximum (17.47 kg/ha) in T_6 and was on par with uptake upto

40th day (T_{11} and T_5) and were superior to all other treatments. Plots weeded after 30th day (T_{10}, T_{15} and T_4) were on par. Uptake upto 20th day (T_{14}, T_9 and T_3) were on par with T_4 and plots having nil uptake (T_2, T_8 and T_{13}) on the 10th day.

b. At harvest

Unweeded check (T_{16}) recorded the maximum nitrogen uptake at harvest (23.99 kg/ha) and was on par with plot weeded 1-10 days (T_1). Plots weeded 11-20 (T_2) and 1-20 (T_7) days were on par and both were significantly lesser than T_{16} and T_1 but significantly higher than all the other treatments which were having the lowest level of N uptake ranging from 0.30 to 4.33 kg/ha.

c. Total

Unweeded check (T_{16}) had the maximum total N uptake by weeds (23.99 kg/ha) and was on par with plot weeded very early, T_1 (weeded 1-10 days) and plot weeded very late, T_6 (weeded 51-60 days). Plots weeded 41-50 (T_5), 41-60 (T_{11}), 11-20 (T_2) and 1-20 (T_7) days had the next higher level of N uptake by weeds (12.09 - 15.34 kg/ha) and were significantly lesser than T_{16} and T_1. All the other treatments were on par and had lower N uptake by weeds (0.30 - 7.01 kg/ha).

Table 11a

Nitrogen uptake by weeds kg/ha

Treatments (Weed free day after transplanting)		Pre-weeding	At harvest	Total
T_1	1-10	-	23.83	23.83
T_2	11-20	0	12.11	12.11
T_3	21-30	0.61	4.33	4.94
T_4	31-40	4.53	2.48	7.01
T_5	41-50	14.17	1.17	15.34
T_6	51-60	17.47	1.07	18.54
T_7	1-20	-	12.09	12.09
T_8	11-30	0	3.84	3.84
T_9	21-40	0.64	2.59	3.23
T_{10}	31-50	5.83	1.07	6.90
T_{11}	41-60	14.42	0.52	14.94
T_{12}	1-30	-	3.45	3.45
T_{13}	11-40	0	2.27	2.27
T_{14}	21-50	1.01	1.24	2.25
T_{15}	31-50	5.57	0.60	6.17
T_{16}	Weedy check	--	23.99	23.99
T_{17}	1-60	--	0.30	0.30
	C.D (0.05)	4.765	5.732	7.589

Among the plots weeded at 10, 20 and 30 day intervals the least N uptake were in plots weeded 21-30 (4.94 kg/ha) 21-40 (3.23 kg/ha) and 21-50 (2.25 kg/ha) days after transplanting, respectively.

In weedy check (T_{16}) the N accumulation by weeds continued upto harvest and the rate of increase were 4.75, 17.55, 37.52, 14.75, 13.75 and 11.68 per cents during 11-20, 21-30, 31-40, 41-50, 51-60 and 61 to harvest (80th day) respectively.

2. P_2O_5 uptake by weeds

The analysis of variance tables are presented in Appendix X and the mean values in Table 11b.

a. Pre-weeding.

Uptake of P_2O_5 by weeds upto 50th day was the maximum (5.92 kg/ha) in T_6 and was on par with uptake upto 40th day (T_{11} and T_5) and were superior to all other treatments. Phosphorous uptake upto 30th day in T_{10}, T_{15} and T_4 were on par and significantly higher than that upto 20th day. Uptake upto 20th day (T_{14}, T_9 and T_3) were on par with plots having zero uptake (T_2, T_8 and T_{13}) on the 10th day.

b. At harvest.

Maximum P_2O_5 uptake of 7.92 kg/ha by weeds was recorded in weedy check (T_{16}) and was on par with very early weeded plot T_1 (weeded 1-10 days). Plots weeded upto 20th day (T_2 and T_7) were on par and had significantly lesser P_2O_5 uptake than T_{16} and T_1 and greater than all the other treatments. Plots weeded upto 30th (T_3, T_{12} and T_8) and upto 40th (T_4, T_{13} and T_9) were on par. Treatments T_9 and T_{13} were on par with all other treatments viz., T_5, T_{14}, T_{10}, T_6, T_{15}, T_{11} and T_{17} forming the lower level of P_2O_5 uptake by weeds (0.10 - 0.89 kg/ha).

c. Total.

The maximum P_2O_5 uptake of 7.92 kg/ha was recorded by unweeded check (T_{16}) which was on par with plot weeded 1-10 days (T_1) and were superior to all others. Plots weeded late 51-60 (T_6), 41-50 (T_5) and 41-60 (T_{11}) days were on par. T_6 and T_5 were significantly superior to plots weeded upto 20th (T_7 and T_2), which were on par.

Treatments T_{10}, T_{15}, T_3, T_{12} and T_8 were significantly lesser than T_2 and T_7 and were higher than the lower level of P_2O_5 uptake (0-10 - 1.18 kg/ha) in treatments T_{17}, T_{13}, T_{14} and T_9.

Among the plots weeded at 10, 20 and 30 day intervals the least P_2O_5 uptake by weeds were in plots weeded 21-30 (1.85 kg/ha), 21-40 (1.18 kg/ha) and 11-40 and 21-50 (0.89 kg/ha) days after transplanting respectively.

Table 11 b

P_2O_5 Uptake by weeds (kg/ha)

Treatments (weed free days after transplanting.)		Pre-weeding	At harvest	Total
T_1	1-10	..	7.80	7.80
T_2	11-20	0	4.33	4.33
T_3	21-30	0.28	1.57	1.85
T_4	31-40	1.64	1.05	2.69
T_5	41-50	5.14	0.47	5.61
T_6	51-60	5.92	0.35	6.27
T_7	1-20	..	4.37	4.37
T_8	11-30	0	1.38	1.38
T_9	21-40	0.30	0.88	1.18
T_{10}	31-50	2.11	0.39	2.50
T_{11}	41-60	5.15	0.20	5.35
T_{12}	1-30	..	1.39	1.39
T_{13}	11-40	0	0.89	0.89
T_{14}	21-50	0.46	0.43	0.89
T_{15}	31-60	2.07	0.25	2.32
T_{16}	Weedy check	..	7.92	7.92
T_{17}	1-60	..	0.10	0.10
	CD (0.05)	1.141	0.879	1.217

In weedy check the P_2O_5 uptake by weeds continued upto harvest and the rates of increase were 6.57, 18.21, 41.97, 11.00, 9.61 and 12.64 per cents during 11-20, 21-30, 31-40, 41-50, 51-60 and 61 to harvest (80th day) respectively.

3. K_2O uptake by weeds

The analysis of variance tables are presented in Appendix X and the mean values in Table 11c.

a. Pre-weeding.

K_2O uptake by weeds upto 50th day in T_6 was the maximum (26.51 kg/ha) and was on par with uptake upto 40th day (T_{11} and T_5). Uptake of K_2O upto 30th (T_{15}, T_{10} and T_4)day were the next highest and were significantly lesser than that upto 50th and 40th and greater than that upto 20th day in T_9 and T_3. Uptake upto 20th day (T_{14}, T_9 and T_3) were on par with plots having zero uptake on 10th day (T_2, T_8 and T_{13}).

b. At harvest.

Unweeded check (T_{16}) recorded the maximum K_2O uptake by weeds (30.48 kg/ha) and was superior to all the other treatments. Potash uptake in T_1 (weeded 1-10 days) was superior to the remaining treatments. Plots weeded upto

20th (T_2 and T_7) had the next higher K_2O uptake and was higher than all the others.

K_2O uptake in T_{12}, T_3, T_8, T_{13} and T_9 followed plots weeded upto 20th day. The lower level of K_2O uptake by weeds (0.50 - 2.52 kg/ha) were in treatments T_{17}, T_{11}, T_{15} T_6, T_5, T_{10}, T_{14} and T_4.

c. Total.

Unweeded check (T_{16}) had the maximum K_2O uptake by weeds (30.48 kg/ha) and was on par with plots weeded 1-10 (T_1), 51-60 (T_6) and 41-50 (T_5) days after transplanting, and were superior to all others, except T_{11} (weeded 41-60) which was on par with T_5, T_6 and T_1. Plots weeded 11-20 (T_2) and 1-20 (T_7) had the next higher level of K_2O uptake by weeds. Plots weeded after 30th day (T_{10}, T_{15} and T_4) and plot weeded 21-30 (T_3) were on par forming the next higher level of K_2O uptake. The lowest level of K_2O uptake varied from 0.50 - 5.38 kg/ha and were in treatments T_{17}, T_{13}, T_8, T_{14}, T_9 and T_{12}.

Among the plots weeded at 10, 20 and 30 day intervals the minimum K_2O uptake by weeds were in plots weeded 21-30 (7.03 kg/ha) 11-30 (3.85 kg/ha) and 11-40 (3.21 kg/ha) days after transplanting respectively.

Table 11 c

K_2O uptake by weeds (Kg/ha)

Treatments (weed free days after transplanting)		Pre-weeding	At harvest	Total
T_1	1-10	..	27.87	27.87
T_2	11-20	0	18.19	18.19
T_3	21-30	1.95	5.08	7.03
T_4	31-40	9.28	2.52	11.80
T_5	41-50	22.92	1.50	24.42
T_6	51-60	26.51	1.06	27.57
T_7	1-20	..	16.13	16.13
T_8	11-30	0	3.85	3.85
T_9	21-40	2.09	3.12	5.21
T_{10}	31-50	11.95	1.15	13.10
T_{11}	41-60	23.21	0.67	23.88
T_{12}	1-30	..	5.38	5.38
T_{13}	11-40	0	3.21	3.21
T_{14}	21-50	3.18	1.17	4.35
T_{15}	31-60	11.97	0.99	12.96
T_{16}	Weedy check	..	30.48	30.48
T_{17}	1-60	..	0.50	0.50
	CD (0.05)	6.811	2.206	6.229

Table 11 d

Pattern of nutrient uptake by weeds in weedy check (T_{16})

Number of days after transplanting.	Nutrient uptake by weeds(kg/ha)		
	Nitrogen	Phosphorous (P_2O_5)	Potash (K_2O)
10th	0	0	0
20th	1.14	0.52	3.64
30th	5.35	1.96	11.02
40th	14.35	5.28	23.32
50th	17.89	6.15	27.42
60th	21.19	6.91	29.69
At harvest (80th)	23.99	7.91	30.48

In weedy check the K_2O uptake by weeds continued upto harvest and the rate of increase were 11.94, 24.21, 40.36, 13.45, 7.45 and 2.59 per cents during 11-20, 21-30, 31-40, 41-50, 51-60 and 61 - harvest (80th day) respectively.

B. Nutrient uptake by Crop

The analysis of variance tables corresponding to the total uptake of N, P_2O_5 and K_2O by the crop at harvest are presented in Appendix XI and the mean values in Table 12.

1. Nitrogen uptake

Plot weeded 11-40 days (T_{13}) had the highest nitrogen uptake (88.63 kg/ha) by crop at harvest and was on par with plot weeded 21-50 (T_{14}), 21-40 (T_9), 1-60 (T_{17}) and 31-50 (T_{10}) days after transplanting. Treatments T_{15}, T_3, T_8, T_7 and T_5 were on par with T_4 and T_{12} and in turn with T_2 and the nitrogen uptake varied from 67.86 - 78.44 kg/ha.

Plot weeded 51-60 days (T_6) recorded the lowest nitrogen uptake (57.41 kg/ha) and was on par with unweeded check (T_{16}) and plots weeded 1-10 (T_1) and 41-60 (T_{11}) days.

2. P_2O_5 Uptake

Plot weeded 1-60 days (T_{17}) recorded the maximum P_2O_5 uptake by crop (40.41 kg/ha) at harvest and was on par with plots weeded 11-40 (T_{13}), 31-50 (T_{10}), 21-40 (T_9) 21-50

(T_{14}), 31-60 (T_{15}) and 1-30 (T_{12}) days after transplanting.

Plot weeded 1-10 days recorded the lowest P_2O_5 uptake (28.44 kg/ha) and was on par with unweeded check (T_{16}) and plots weeded 51-60 (T_6), 11-20 (T_2), 1-20 (T_7), 41-60 (T_{11}) and 41-50 (T_5) days after transplanting. Treatments T_{11} and T_5 were in turn on par with T_3, T_4 and T_8.

3. K_2O Uptake.

The maximum K_2O uptake by crop (111.12 kg/ha) was recorded in plot weeded 21-40 days (T_9) and was on par with plots weeded 1-60 (T_{17}), 21-50 (T_{14}), 31-50 (T_{10}), 11-40 (T_{13}) days after transplanting.

Plots weeded 21-30 (T_3), 31-40 (T_4), 11-30 (T_8) and 1-30 (T_{12}) days were also on par and had the next higher level of K_2O uptake by crop.

Treatments T_5, T_{11}, T_2, T_7 and T_{15} were on par and recorded lesser uptake of K_2O/ha (81.36 - 83.80 kg/ha). Unweeded check (T_{16}) recorded the lowest K_2O uptake of 70.04 kg/ha and was on par with plots weeded 51-60 (T_6) and 1-10 (T_1) days.

C. Protein content of Grain

The analysis of variance table is presented in Appendix XI and the mean values in Table 12.

Table 12

Nutrient uptake by crop at harvest (kg/ha) and protein content of grain (%)

Treatments (weed free days after trans-planting.)		N	P_2O_5	K_2O	% protein
T_1	1-10	59.92	28.31	75.40	7.53
T_2	11-20	67.86	28.90	88.30	7.92
T_3	21-30	74.67	34.00	102.45	7.92
T_4	31-40	77.45	34.66	102.45	8.31
T_5	41-50	70.37	33.20	83.80	7.73
T_6	51-60	57.41	28.63	70.18	7.43
T_7	1-20	71.03	29.30	88.89	7.73
T_8	11-30	73.42	34.59	99.28	8.61
T_9	21-40	85.26	37.70	111.12	8.05
T_{10}	31-50	83.67	38.56	105.36	8.59
T_{11}	41-60	63.36	32.48	85.06	7.34
T_{12}	1-30	78.44	35.85	98.81	8.12
T_{13}	11-40	88.63	39.22	104.63	8.20
T_{14}	21-50	86.11	37.30	105.56	8.31
T_{15}	31-60	76.13	35.98	89.36	8.12
T_{16}	Weedy check	57.54	28.44	70.04	7.48
T_{17}	1-60	83.73	40.41	109.46	8.61
CD (0.05)		9.269	4.952	8.436	0.817

Plot weeded 1-60 days (T_{17}) and plot weeded 11-30 days (T_8) recorded the maximum protein content of 8.61 per cent. Treatments T_{17} and T_8 were on par with treatments T_{10}, T_4, T_{14}, T_{13}, T_{15}, T_{12}, T_9, T_3 and T_2. Plot weeded 41-60 (T_{11}) recorded the least protein percentage (7.34) and was on par with treatments T_6, T_{16}, T_1, T_7, T_5, T_2, T_3, T_{12} and T_{15}.

V. Correlation studies

The values of simple correlation coefficients are presented in Table 13. All the correlations were highly significant.

Dry weight of weeds were negatively correlated with the total dry matter produced by crop and the grain yield the 'r' values were -0.9438 and -0.8292 respectively.

N, P_2O_5 and K_2O uptake by crop were positively correlated with grain yield and negatively with weed dry matter production and the correlation coefficients were; 0.8803, 0.8781, 0.8001, -0.8513, -0.6738 and -0.9031 respectively.

N, P_2O_5 and K_2O uptake by weeds were negatively correlated with the grain yield, the 'r' values being -0.7400, -0.8412 and -0.7998 respectively. The N, P_2O_5 and K_2O uptake by weeds were negatively correlated with N, P_2O_5 and K_2O uptake by crop respectively and the values of correlation coefficients were -0.7913, -0.6991 and -0.8939 respectively.

Table 13

Values of simple correlation coefficients

Sl. No.	Characters correlated			Correlation coefficient
1.	Dry matter production by crop.	x	Dry matter production by weeds.	-0.9438**
2.	Grain yield	x	Dry matter production by weeds.	-0.8292**
3.	Grain yield	x	N uptake by crop	0.8803**
4.	Grain yield	x	P_2O_5 uptake by crop	0.8781**
5.	Grain yield	x	K_2O uptake by crop	0.8001**
6.	Grain yield	x	N uptake by weeds	-0.7400**
7.	Grain yield	x	P_2O_5 uptake by weeds.	-0.8412**
8.	Grain yield	x	K_2O uptake by weeds.	-0.7998**
9.	Dry matter production by weeds.	x	N uptake by crop	-0.8513**
10.	Dry matter production by weeds.	x	P_2O_5 uptake by crop.	-0.6738**
11.	Dry matter production by weeds	x	K_2O uptake by crop.	-0.9031**
12.	N uptake by crop	x	N uptake by weeds	-0.7913**
13.	P_2O_5 uptake by crop	x	P_2O_5 uptake by weeds.	-0.6991**
14.	K_2O uptake by crop	x	K_2O uptake by weeds.	-0.8939**

** Significant at 0.01 level.

DISCUSSION

DISCUSSION

An experiment was conducted in the Instructional Farm attached to the College of Agriculture, Vellayani, during the second crop season of 1976-77, to study the critical periods of weed infestation and the effect of weed growth on the yield and quality of a short duration rice var. Triveni. The results of the experiment are discussed below.

1. Observations on Weeds

A. Weed species

Observations revealed that weed species belonging to grasses, sedges and broad-leafed weeds, competed with the rice crop. The most serious weeds during the season were *Echinochloa crus-galli*, *Brachiaria ramosa* and *Ischaemum rugosum* among grasses, *Cyperus* spp. and *Fimbristylis miliacea* among sedges and *Monochoria vaginalis* and *Ludwigia parviflora* among broad-leafed weeds. *Salvinia molesta*, a floating weed, was also noted in the field.

B. Weed Count

During 1-10 days after transplanting the weeds could not be differentiated and so counts were taken only on 20th, 30th, 40th, 50th and 60th day after transplanting and at harvest.

1. Monocot weed population

The data in Table 2a and the Figs. 4a, b, c and d showed that the monocot weed population increased significantly upto 40th day of transplanting, after which it was not significant. Similarly the re-emergence of monocot weeds 10 days after weeding also showed that the number was highest between 31-40 days after transplanting, which was on par with that during 21-30 and 11-20 days and superior to re-emergence during 41-50 and 51-60 days. This shows that the monocot weeds were higher in plots between 11-40 days after transplanting, before weeding as well as 10 days after weeding. The monocot weed count at harvest indicates that maximum weeds($405.0/m^2$) were in weedy check. The population at harvest decreased as weeding was delayed.

Further it may be noted that if a weed free condition of 10 days has to be provided, it may be between 31-40 days after transplanting; 11-30 or 21-40 days for a 20 day period and 11-40 days for a 30 day period.

The rate of increase of monocot weed population as indicated by the weed count in weedy check showed that it reached a maximum of 36.45 per cent during 31-40 days after which it got reduced (Table 3b). By 40th day of transplanting the crop has completed its tillering and has established in the field enabling them to compete better and suppress the rate of increase in the monocot weed population.

So it may be concluded that the critical period of monocot weed infestation in rice crop lies between 11-40 days after transplanting.

2. Dicot weed population

The results showed that the dicot weed population increased significantly upto 40th day of transplanting and was on par with that upto 50th day. Like monocot weeds, 11-40 days after transplanting was also found to be the period of maximum dicot weed infestation in rice field.

Dicot weed emergence 10 days after weeding was maximum ($86.8/m^2$) between 11-20 days, which was on par with that during 21-30 and were significantly greater than the later emergence. Hence the important period of dicot weed emergence after weeding, may be considered as 11-30 days.

Dicot weed population at harvest showed that it was higher in early weeded plots and maximum ($313.0/m^2$) in weedy check, indicating that dicot weed emergence was more during early stages of the crop growth.

Further it may be noted that if a 10 day weed free condition has to be provided it may be given between 11-20 days after transplanting; 11-30 for 20 day periods and 11-40 for 30 day periods indicating again that 11-40 may be the critical period of dicot weed growth in rice.

The rate of increase in dicot weed population as observed in the weedy check reached a maximum of 43.28 per cent during 21-30 days and reached cent percent by 40th day ($372.0/m^2$). The number decreased thereafter till harvest. (Table 3b).

The reduction in dicot weed number and the very slow rate of increase after 40th day showed that the dicot weeds were not strong competitors for the rice crop compared to the monocots, during the later stages.

3. Total weed population

The increase in total weed population was significant upto 40th day after transplanting and was not significant afterwards. So 11-40 days after transplanting may be considered as the period of maximum weed infestation in rice crop, taking into account both the monocot and dicot weeds together.

Total weed emergence 10 days after weeding, was maximum ($131.0/m^2$) during 21-30 days which was on par with that during 11-20 days. So the maximum post weeding emergence occured during 11-30 days, as in dicots.

Total weed population at harvest was maximum ($719.0/m^2$) in weedy check, followed by early weeded plots indicating that as weeding was delayed the total weeds at harvest also got reduced. Khan et al. (1969) noticed that the weed re-emergence was considerable in early weeded plots.

Further it may be noted that among the 10 day, 20 day and 30 day weed free periods tried, the minimum weed populations were observed in treatments having weed free periods of 21-30, 11-30 and 11-40 days respectively. This shows that the critical period of weed infestation in rice may be from 11-40 days after transplating.

The rate of increase in the total weed population (Table 3b and Fig. 4d) was maximum (34.04 per cent) during 31-40 days in weedy check. During 11-40 day period, 86.11 per cent of the total weeds emerged.

The decrease or levelling off in weed population after 40th day may be because, the crop could suppress weed emergence better as the days advanced or the crop as well as the already emerged weeds prevented further emergence. Ravindran (1976) got similar results.

From the tables 2a, b, c and 3b and figures 4a, b, c and d, it may be noted that the dicot weeds were more during the early stages of crop growth and that they got reduced afterwards, while the monocot weeds got an upper hand during the later stages of the crop. The maximum post-weeding, emergence occured during 31-40 days for monocots and 11-20 days for dicots. The dicot weed population in weedy check got decreased after 40th day of transplanting whereas the monocots increased in number even after 40th day. All these indicated that the monocot weeds were found to be better competitors in rice crop, than dicots during the later stages of the crop.

The monocot weeds having similar growth habit could compete with the rice crop efficiently than dicots. Some of the monocots were perennial in nature compared to many seasonal dicots. Monocot weeds like Echinochloa crus-galli, Echinochloa colonum, Oryza sativa var. fatua etc. had growth habit similar to rice and so the rice crop could not suppress them as they could do with the dicot weeds such as Monochoria vaginalis, Ludwiga parviflora etc. The above finding is in agreement with that of Muzik (1970).

C. Dry Matter Production by Weeds

Dry matter production upto 20th day (3.85 - 6.20 g/m^2) after transplanting and that upto 10th day (nil) were on par. Accumulation upto 40th day (85.86 - 85.90 g/m^2) was superior to that upto 20th and 30th day, but was on par with that upto 50th day (105.19 g/m^2). Therefore, the dry matter accumulation during 21-40 days may be considered critical.

Burnside and Wicks (1967) got similar pattern of weed dry matter accumulation in sorghum. Shetty and Gill (1974) also found that delaying weeding beyong 4-6 weeks increased weed dry matter.

The dry matter production at harvest was maximum in weedy check (154.18 g/m^2). As weeding was delayed the dry matter accumulation decreased at harvest. Plots weeded upto and after 40th day generally produced very low dry matter till harvest (2.00 - 16.67 g/m^2).

With regard to total dry matter production weedy check, plots weeded upto 20th day and plots weeded after 40th day produced comparatively higher dry matter by weeds. Plots weeded 21-40 days for a minimum of 10 days produced very low total dry matter by weeds (12.78 - 41.50 g/m^2). So it may be concluded that the critical period of weed dry matter accumulation, was between 21-40 days after transplanting. This is in agreement with the finding of Ravindran (1976).

From table 3a it may be noted that among the 10 day interval weed free treatments 21-30 day period reduced the total dry matter to the minimum of 27.90 g/m^2; for a 20 day period, it was 21-40 days (19.90 g/m^2) and for a 30 day period it was 21-50 days (12.78 g/m^2) after transplanting. The plots weeded 21-40 day and 21-50 days, were on par with

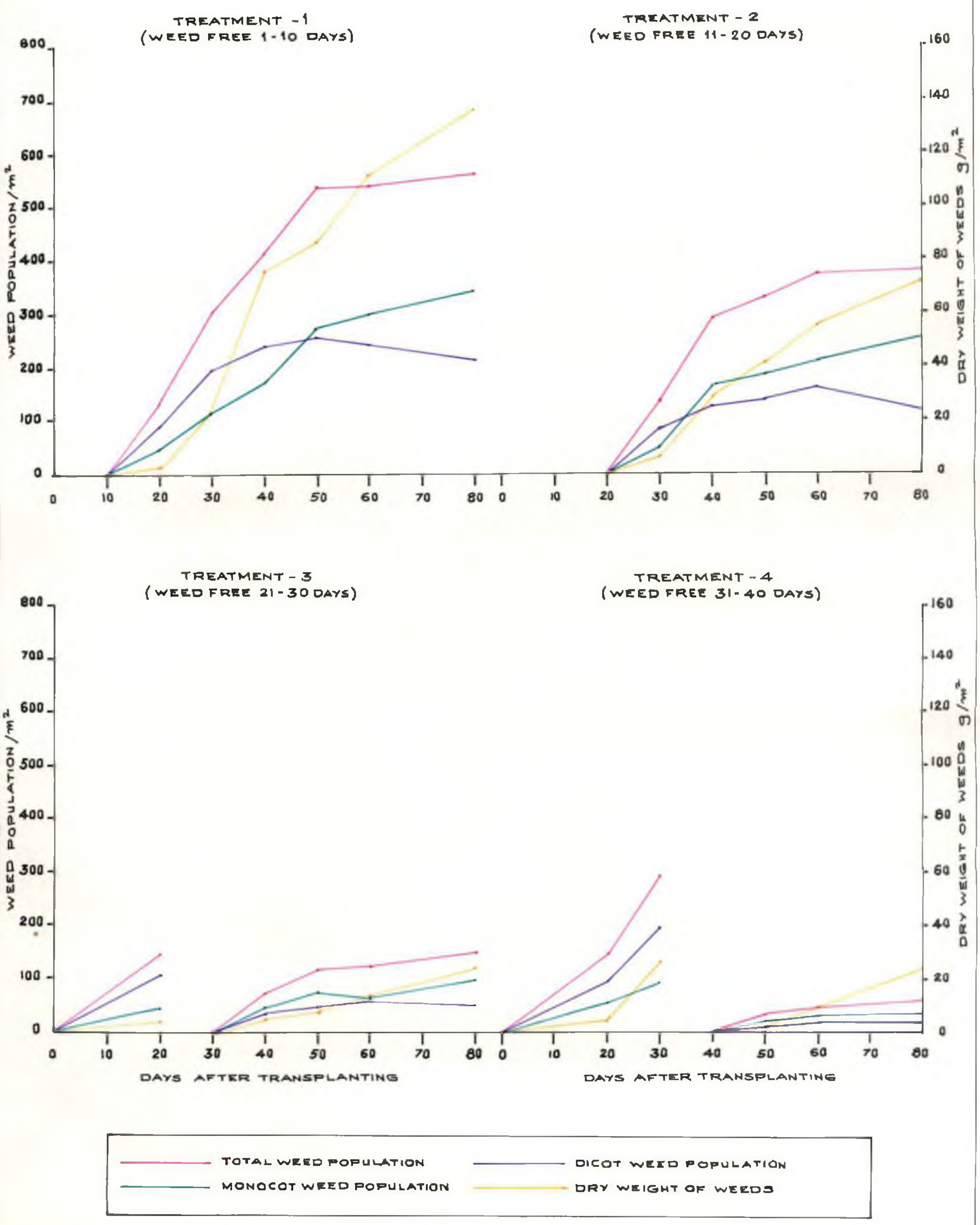


FIG. 4. a. EFFECT OF WEED FREE PERIODS ON WEEDS.

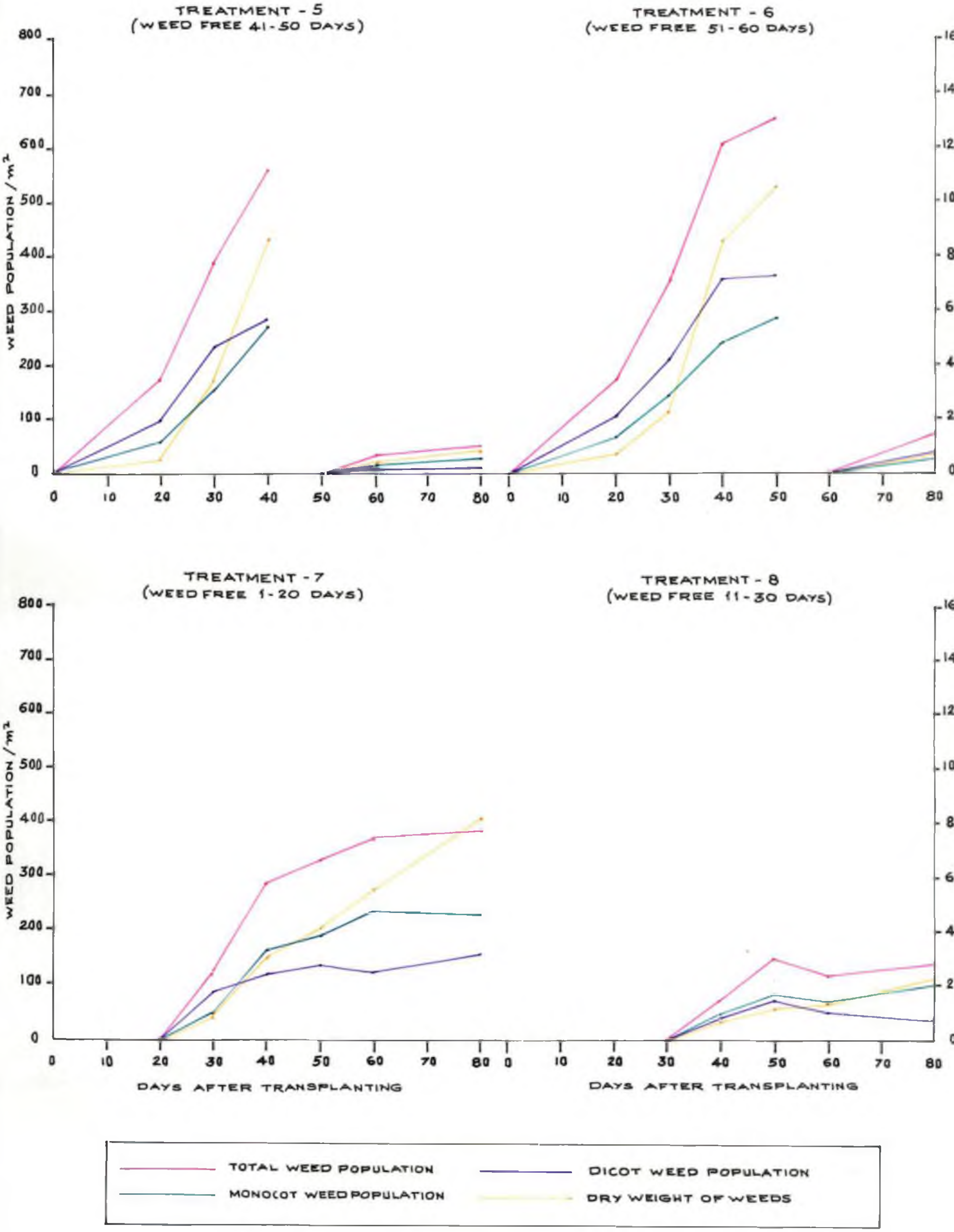


FIG. 4.b. EFFECT OF WEED FREE PERIODS ON WEEDS.

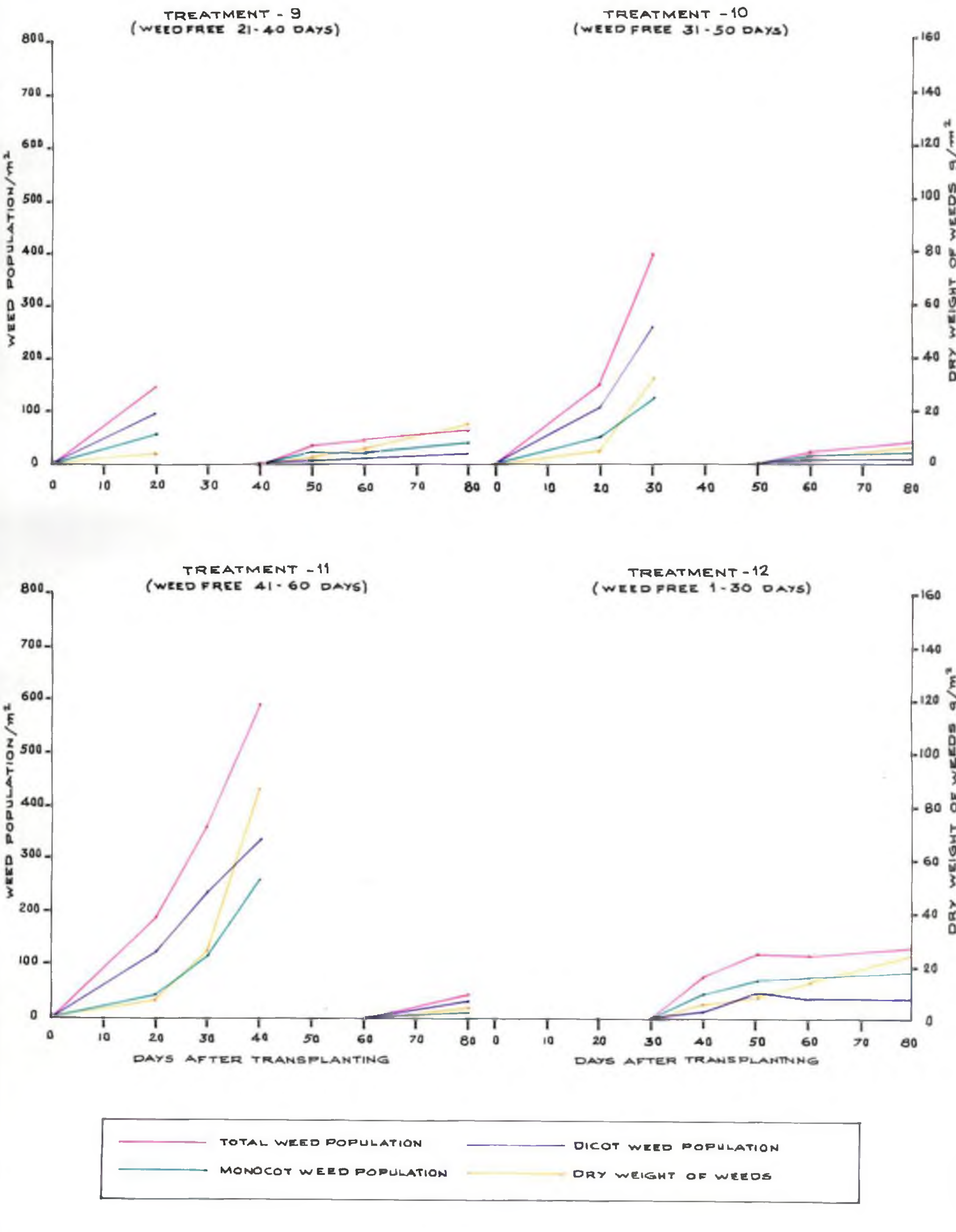


FIG. 4.C. EFFECT OF WEED FREE PERIODS ON WEEDS.

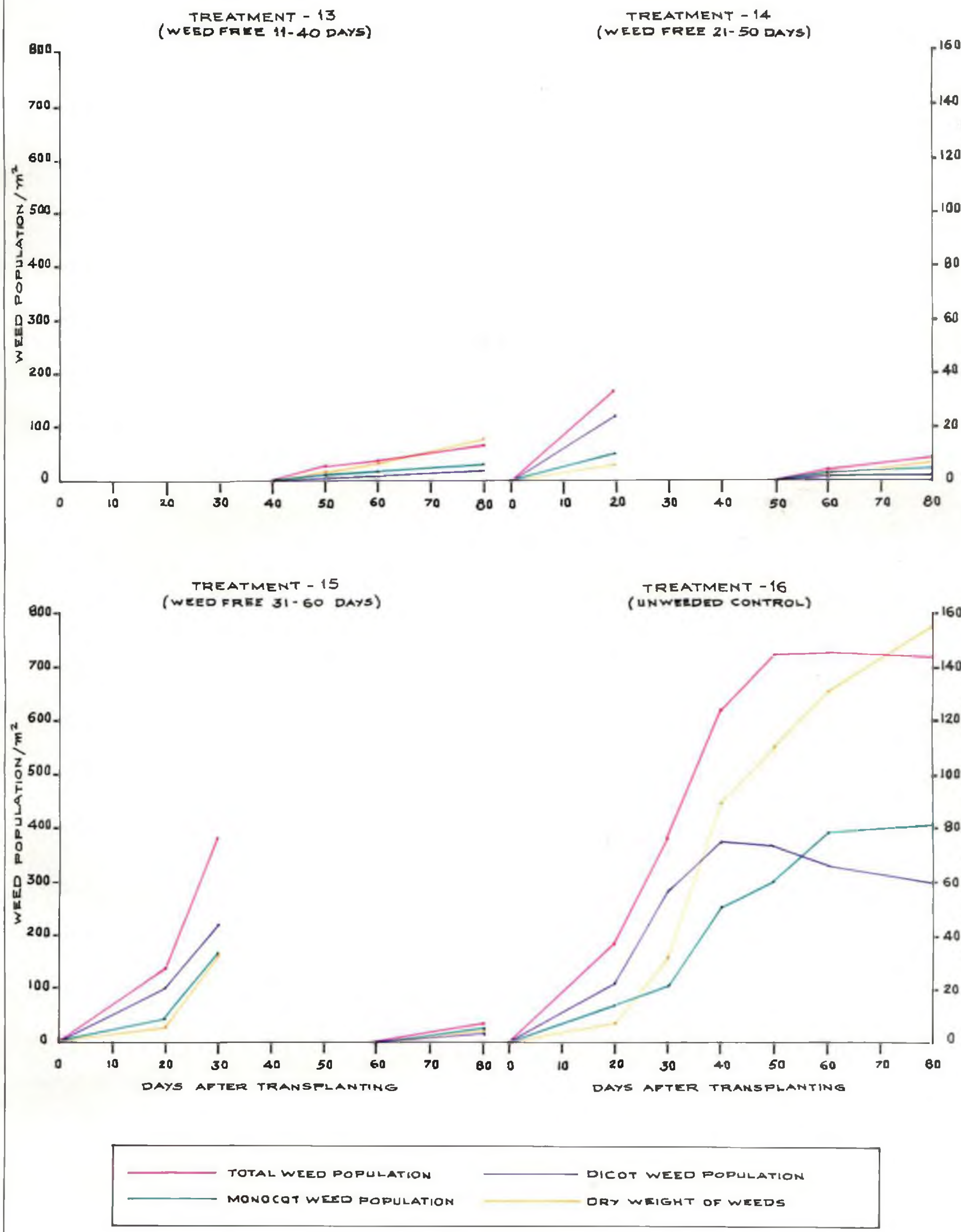


FIG. 4.d. EFFECT OF WEED FREE PERIODS ON WEEDS.

plot weeded 1-60 days (2.00 g/m^2) with regard to total dry matter production.

In weedy check the weed dry matter accumulation was maximum (37.27 per cent of total) during 31-40 days, whereafter the increase was at a decreasing rate and almost got levelled off after 60th day. By 40th day the weeds accumulated 57.36 percentage of the total dry matter.

The low dry matter production in plots weeded 21-40 days was due to the removal of 86.11 per cent of the total weed population, (discussed earlier). The weeds that emerged after 40th day were not able to accummulate sufficient dry matter since the competition between the weeds as well as between the crop and weeds had become very severe, whereby the weeds were suppressed by the well established crop. Muzik (1970) has reported that weed competition was more severe, during early periods of crop growth.

II. Crop Growth Characters

a. Plant height

Plant height was not affected significantly by weeds during any stage of crop growth. A trend in reduction of height was observed during the later stages of crop growth in weedy check and late weeded plots compared to weed free plots (Table 4).

There was less shading effect on crop due to weeds, except by barnyard grass and umbrella sedge which over grew the crop only in the late stage.

Similar results were obtained by Anon (1967) Shetty and Gill (1974) Mohammed Ali and Sankaran (1975), while Misra and Roy (1974) and Sharma (1977) noted significant reduction in plant height due to weeds.

b. Tiller number

The tiller number was not significantly affected by the treatments. The tillering was completed by 30th day after transplanting and the weed growth upto 30th day was not sufficient enough to suppress or reduce the tiller production.

Shetty and Gill (1974) and Ravindran (1976) did not notice reduction in tiller number due to whole season weed competition, compared to hand weeded plots. Contrary to this many workers like, Swain (1967), Kleing and Noble (1968), Noda et al. (1968), Chang and Datta (1972), Swain et al. (1975) and Narayanaswami (1976) noted reduced tiller number in rice due to weeds.

c. Leaf area index

The leaf area index was not affected by weeding periods. The index attained the maximum by 40th day, after which it decreased. This decrease may be due to the dying out of older leaves and some tillers.

Pande and Bhan (1976) noticed increase in leaf area index due to weeding in upland rice.

III. Yield Characters

a. Productive tillers and percentage of productive tillers

From the data in table 7, it may be noted that in general, plots receiving early weeding during 11-40 days produced more number of productive tillers (278.0 - 331.5 $/m^2$) compared to plots receiving weedings after 40th day or during 1-10 days (207.5 - 251.0/m^2).

The nitrogen uptake by the crop during the tillering and panicle initiation stages, decides the number of productive tillers in rice. The weed competition for nitrogen was maximum during 21-40 days after transplanting. Therefore, those plots which were free of weeds during 11-40 days had higher number of productive tillers than others.

Arai (1967), Main and Rahaman (1969), Chang and Datta (1972) Mohammed Ali and Sankaran (1975), Narayanaswami (1976), Ravindran (1976) and Sharma et al. (1977) noticed reduction in productive tillers due to weed competition in transplanted rice.

Similarly the percentage of productive tillers was higher in plots weeded during 11-40 days (66.40-78.04 per cent) than those in weedy check as well as plots weeded 1-10 days and after 40th day of transplanting (53.43 - 62.40 per cent).

The lesser number and percentage of productive tillers indicated the severity of competition for nutrients especially nitrogen by weeds during the vegetative phase of the crop.

b. Length of panicle

Length of panicle was not affected by none of the treatments, since it may be a varietal character, or the competition might not have been severe enough to affect the panicle length significantly.

Ravindran (1976) and Sharma et al. (1977) noted that panicle length was not affected by weed competition, whereas Noda et al. (1968) and Shetty and Gill (1974) noted reduction in panicle length.

c. Number of spikelets per panicle

The data presented in table 8, showed that the spikelet number in weedy check was the lowest (56) which was on par with plots weeded at 10 and 20 day intervals between 1-20 and 41-60 days after transplanting.

This shows that in plots weeded early and those weeded after 40th day weeds grew with crop and competed with them during the tillering, panicle initiation and booting stages of the crop.

Those plots, in which a portion or complete weed free period had fallen within 21st and 40th days after transplanting produced higher number of spikelets/panicle (67-80).

Arai (1967) and Kleing and Noble (1968) reported reduction in number of spikelets per panicle due to competition from Echinochloa.

d. Number of filled grains and weight per panicle

As in the case of spikelet number, early weeding upto 20th day and weeding after 40th day did not help in increasing the number of filled grains and weight of panicle. The maximum number of 53 filled grains per panicle were noted in plot weeded 21-50 days and plot weeded 31-50 had maximum weight per panicle (1.71 g.). Weeding for a 10 or 20 day period during 21-40 days was able to reduce the weed competition considerably as discussed early. Reduced competition during panicle initiation, R/D stage and loading stages might have helped in increasing the number of filled grains and weight of panicle.

Arai (1967), Main and Rahaman (1969), Yogeswara Rao and Padmanabhan (1972), Narayanaswami (1976), Ravindran (1976) and Sharma et al. (1977) noted that number of grains per panicle was reduced by weed competition in transplanted rice.

e. Percentage of filled grains per panicle

The percentage fertility was unaffected by the treatments. This may be because that it is a varietal character. The above finding is in agreement with that of Kleing and Noble (1968).

f. 1000 grain weight

None of the treatments had any significant effect on weight per grain. Main and Gaffer (1971), Yogeswara Rao and Padmanabhan (1972), Ravindran (1976) supported the above finding, whereas Noda et al. (1968), Chang (1970) and Noda et al. (1971) noticed reduction in 1000 grain weight due to weed competition.

g. Grain yield

The data presented in Table 9 showed that the maximum grain yield of 3466 kg/ha was recorded in plot weeded 1-60 days after transplanting, which was on par with plots weeded at 10 day intervals between 21-40 days, at 20 day intervals between 11-50 days and at 30 day intervals between 1-60 days. The lowest yield of 2533 kg/ha was recorded in weedy check, which was on par with plots weeded 1-10, 41-60 and 51-60 days after transplanting. This shows that the critical period of crop weed competition lies between 21-40 days after transplanting and that weeding very early or later than 40th day reduced crop yields significantly.

The plots receiving weeding between 21-40 days in general had higher productive tiller number, percentage productive tillers, number of spikelets, number of filled grains and weight per panicle. These yield attributing characters might have helped in increasing the grain yield.

The above findings are similar to that of Anon (1967), Anon (1970 a), Park and Kim (1971) Chang and Mao (1972), Khan <u>et al</u>.(1974), Panchal and Sastry (1974), Shetty and Gill (1974), Smith (1974), Ghosh <u>et al</u>.(1975) and Nair <u>et al</u> (1975).

Among the 10, 20 and 30 day weed free intervals tried plot weeded 21-30, 21-40 and 21-50 days after transplanting recorded the maximum yield for the respective groups. This points to the fact that weeding need be started from 21st day of transplanting. Plot weeded 21-30 days recorded an average yield of 3248 kg/ha. When the weed free period was extended by 10 days (21-40) the yield was increased by 59 kg/ha over that of plot weeded 21-30 days, which work out to 5.9 kg/ additional weed free day. Again as the weed free period was extended by another 10 days (21-50) the yield increase over plot weeded 21-40 days was 99 kg/ha which was equal to 9.9 kg/additional weed free day. Plot weeded 1-60 days produced only 60 kg additional yield/ha over plot weeded 21-50 days. So the increase works out to only 2 kg/additional weed free day.

So it may be concluded that weeding may be started from 21st day and extended till 50th day after transplanting for maximum yields. The shortest weeding period of 10 days which gave the highest yield as good as the maximum obtained from plot weeded 1-60 days may be taken as 21-30 days after transplanting.

Anon (1964), Anon (1965), Vega et al.(1967) Anon (1970a) Chang (1970a) Bhan et al.(1974), Panchal and Sastry (1974), Shetty and Gill (1974), Smith (1974), Ghosh et al.(1975), Nair et al.(1975), Mohammed Ali and Sankaran (1977) and Sharma et al.(1977) all got similar results.

Plot weeded 21-50 days produced 3406 kg/ha of grain yield with a reduction of 1.73 per cent compared to the maximum yield recorded by plot weeded 1-60 days. From the data

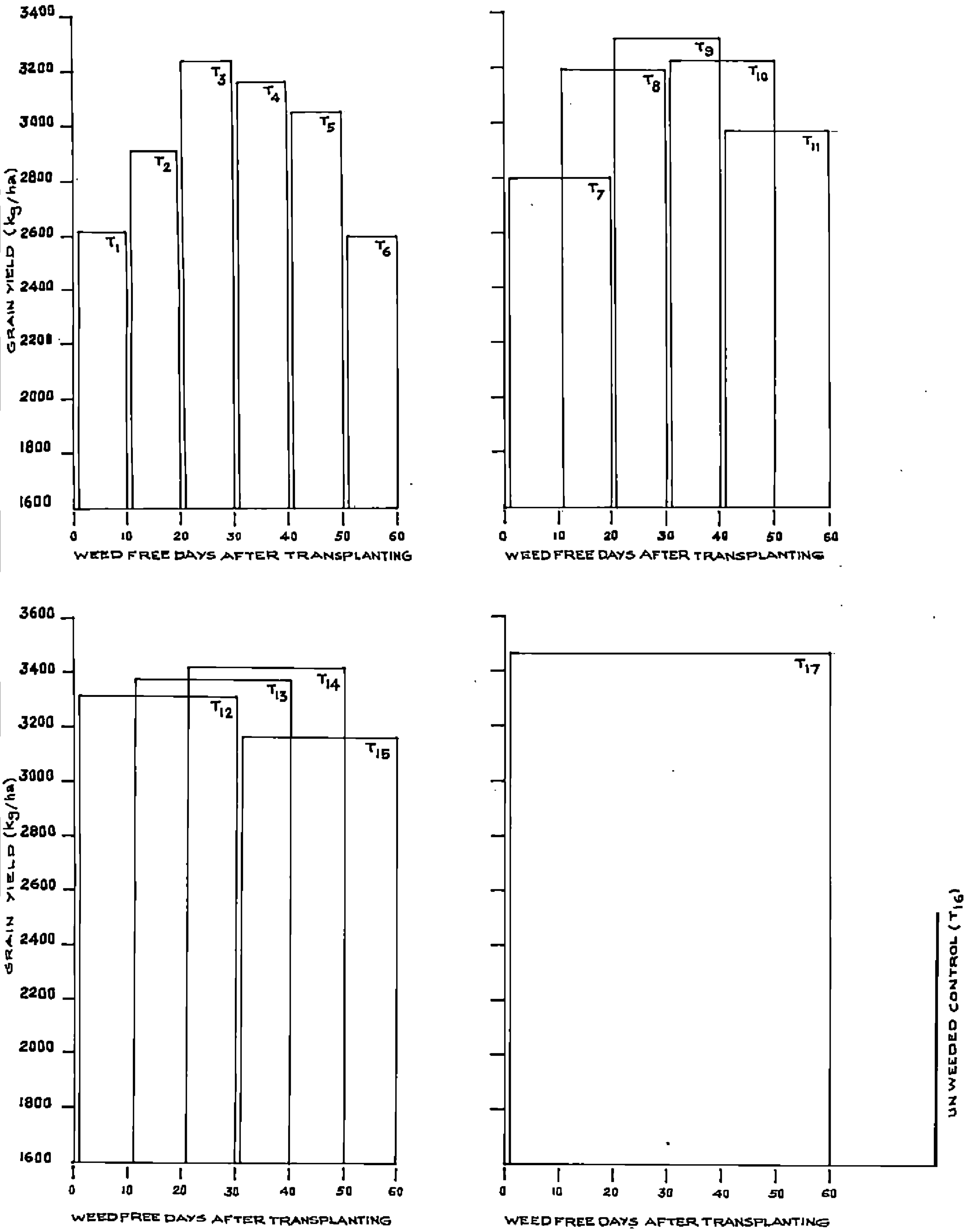


FIG. 5. GRAIN YIELD OF RICE AS AFFECTED BY WEED FREE PERIODS.

in Table 3a it may be noted that weed population during 1-20 days and after 50th day upto harvest in the plot weeded 21-50 days accumulated a total dry matter of only 12.78 g/m^2. This shows that the dry matter accumulation was not sufficient enough to reduce the yield much. So the variation in yield between plot weeded 1-60 days and 21-50 days may be considered negligible.

The difference between percentage yield reductions due to whole season weed competition (26.91) and that in plot weeded 51-60 days (25.01) is also negligible indicating that maximum grain yield reduction due to weed competition occur during 21-50 days after transplanting. Anon (1965), Vega et al (1967) and Cheng and Mao (1972) got similar results.

h. Straw yield

From the table 9 it may be noted that early weeding upto 20th day and late weeding after 40th day in general produced lesser straw yields than plots having maximum straw yield of 3658 kg/ha in plots weeded 31-50 and 11-40 days. Plots weeded 21-40 days for a minimum of 10 days generally produced straw yield which were on par with the maximum yield.

This may be due to the removal of weeds during the critical periods of infestation, whereby the crop had absorbed more of the nutrients and resulted in higher straw yields.

(i) Weed index

Weed index is the reduction in yield due to the presence of weeds in comparison with plot having minimum weeds.

The maximum weed index of 25.47 was recorded in weedy check followed by plots weeded 1-10 and 51-60 days. Plot weeded 11-40 days had the least index of 0.78, and hence may be considered as the ideal weeding period for maximum yield, of grain and straw together.

The weed dry matter constituted 22.57 per cent of the total dry matter production by crop plus weed, in unweeded check and was able to reduce the crop dry matter production by 1808 kg/ha as compared to plot having minimum weeds. In plots having lesser weeds the yield reduction was also lesser.

The total dry matter production by crop plus weed in unweeded control was 6831 kg/ha which was less than the dry matter production by crop alone in plot weeded 1-60 days (7097 kg/ha). Due to severity of competition between crop and weed both were not able to accumulate dry matter equal to that of their species, when grown alone.

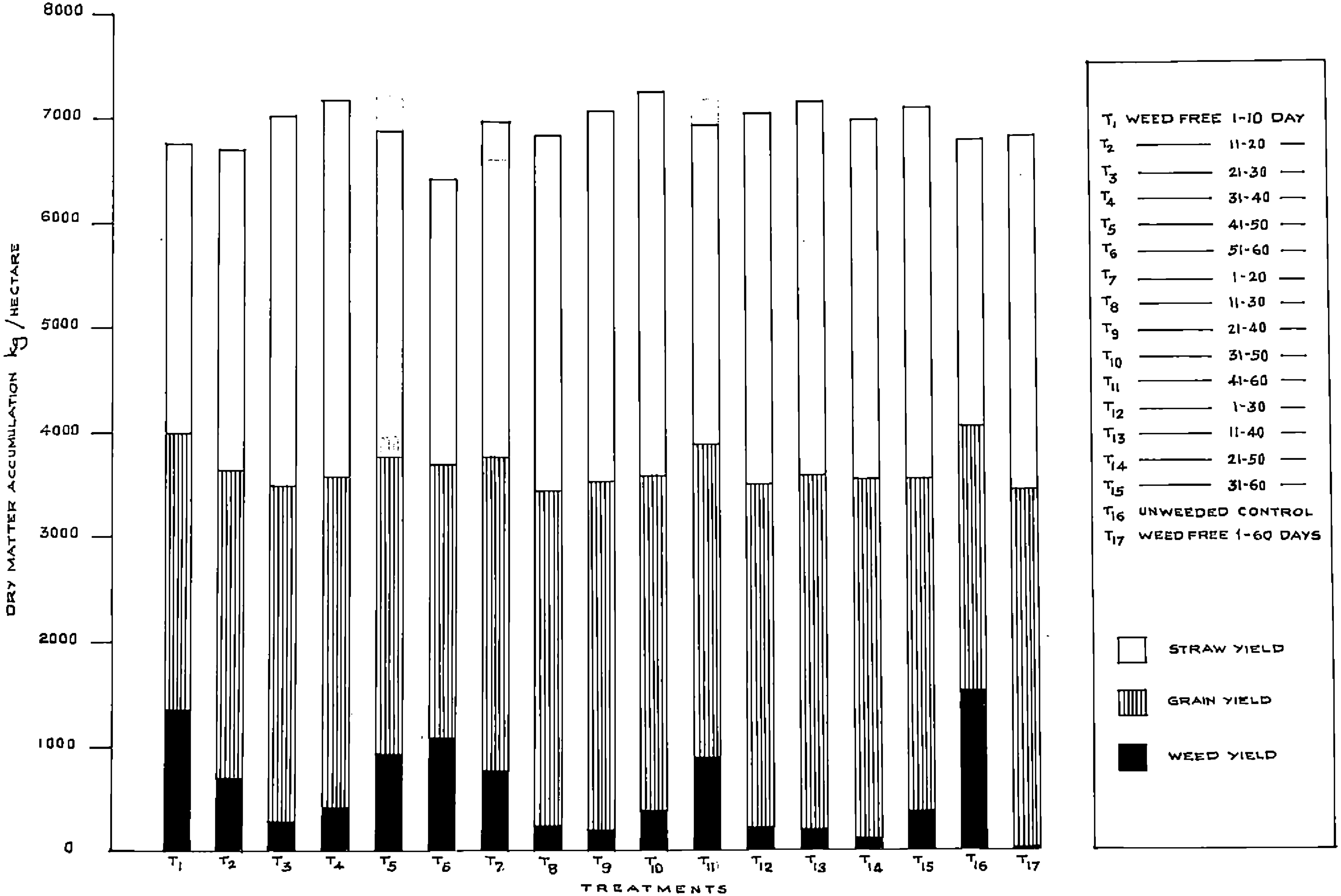


FIG. 6. EFFECT OF WEED FREE PERIODS ON WEED GRAIN AND STRAW YIELDS.

IV Chemical Analysis

A. Nutrient uptake by weeds

From the table 11a, b, and c it can be observed that the pattern of uptake of N, P_2O_5 and K_2O by weeds were similar, and so have been discussed together as nutrient's below. There were no significant difference in the uptake of nutrients on 10th day and 20th day after transplanting. In general the uptake increased significantly upto 40th day whereafter it was not significant, eventhough nutrient uptake continued till harvest. This suggests that the nutrient uptake by weeds was maximum during 21-40 days. Noda *et al.* 1968 and Datta *et al.* (1969) noted competition for N during the first half of the growing season. Shetty and Gill (1974) also got similar results.

The uptake of nutrients by weeds at harvest was maximum in weedy check, followed by early weeded plots, ie. upto 10th or 20th day after transplanting. Plots weeded after 20th day had in general low nutrient uptake at harvest.

With regard to total nutrient removed by weeds the weedy check had the maximum uptake of 23.99 kg N, 7.92 kg P_2O_5 and 30.48 kg K_2O/ha. Plots weeded after 40th day and upto 10th or 20th day had higher nutrient removal than all the other treatments indicating that weeding during 21-40 days reduced the nutrient uptake by weeds considerably (Fig. 7). Plots weeded 1-60 days recorded the least uptake of the three major nutrients. So it may be concluded that 21-40 days may be considered as the critical period of nutrient uptake by weeds in rice fields.

The data on nutrient uptake by the weeds in the weedy check presented in Table 11 d, showed that the maximum uptake of N, P_2O_5 and K_2O was during 31-40 days after transplanting. The corresponding percentage of uptake were 37.52, 41.97 and 40.36 respectively of the total removal of each nutrient. Since the critical period of nutrient uptake was considered as 21-40 days the percentage of N, P_2O_5 and K_2O uptake by the weeds during that period were 55.07, 60.18 and 64.57 respectively in weedy check.

Among the 10 day weed free intervals tried the period between 21-30 days was found to be the best time in reducing the uptake of the three major nutrients by the weeds. As regards to the 20 day periods, 21-40 days was considered ideal for reducing the N and P_2O_5 uptake whereas 11-30 days was best for reducing K_2O uptake. Among the longer intervals of 30 day periods tried 21-50 days was found to be the best time for reducing the uptake of N and P_2O_5 and 11 - 40 for P_2O_5 and K_2O uptake.

This indicates that among the three major nutrients the weeds removed K_2O as early as 11th day of transplanting, whereas N and P_2O_5 from 21st day onwards.

B. Nutrient uptake by crop

1. Nitrogen uptake by crop

From the data in Table 12 and Fig. 7 it may be noted that the lowest N uptake by crop (57.41 kg/ha) was in plots weeded 51-60 days which was on par with that in weedy check and plots weeded 1-10 and 41-60 days after transplanting.

This may be because that crop suffered from weed competition for nitrogen during 21-40 days. In short duration varieties of rice, the major requirement for N occur by 40th day after transplanting during which the tillering and panicle initiation take place. The competition from weeds might have resulted in lower uptake of nitrogen by crop. It may also be noted that the crop has absorbed a maximum quantity of 88.63 kg N/ha from plot weeded 11-40 days after transplanting, which was on par with plots weeded 21-40 days for a minimum of 10 days and plot weeded 1-60 days.

Similar findings were reported by earlier workers like Noda *et al.* (1968) and Chang and Datta (1969). Mikkelson (1970) has noted that N accumulation occured rapidly during the vegetative phase and found that critical N requirements in rice were during tillering, panicle initiation, R/D stage and full heading stage.

2. P_2O_5 uptake by crop

Plots weeded very early (1-10 days) recorded the minimum P_2O_5 uptake of 28.44 kg/ha by crop and was on par with weedy check, plots weeded upto 20th day and plots weeded after 40th day.

This indicated that the maximum phosphorous requirement by crop occured during 21-40 days after transplanting. During this period if the weeds remain in the field they could absorb substantial quantities of P_2O_5, as already observed whereby the plant absorption may be adversely affected.

Plot weeded 1-60 days recorded maximum P_2O_5 uptake of 40.41 kg/ha by crop which was on par with P_2O_5 uptake in plots weeded during 21-40 days, at 10 or 20 day intervals. This is in agreement with the finding of Mikkelson (1970).

3. K_2O uptake by crop

From the table 12 and Fig. 7 it can be noted that maximum K_2O uptake by crop was recorded in plot weeded 21-40 days (111.12 kg/ha) which was on par with plot weeded 1-60 days (109.46 kg/ha). The least uptake of 70.04 kg/ha of

K_2O by crop was in weedy check which was on par with plots weeded 51-60 and 1-10 days.

This shows that crop suffered from weed competition for potash during 11-50 days, during which period the weeds accumulated substantial quantities of K_2O.

The potash absorption in rice was faster than that of N and P. By booting stage nearly ¾ of the K requirement would be absorbed by the crop (Mikkelson 1970).

So when a short duration rice crop was faced with a competition by weeds for potash, upto 40th or 50th day of transplanting the crop may not be able to absorb the required quantity of K, which can be observed from Fig. 7.

It may be noted from the data of the unweeded check that the N, P_2O_5 and K_2O uptake by weeds constituted 29.48, 21.77 and 30.32 per cents of the total N, P_2O_5 and K_2O removed by crop plus weed. The total N, P_2O_5 and K_2O uptake by crop plus weed in unweeded check were 81.53, 36.36 and 100.52 kg/ha respectively, which were less than the uptake by crop alone in plot weeded 1-60 days; the uptake being 83.73, 40.41 and 109.46 kg/ha of N, P_2O_5 and K_2O respectively. Similar trend was noted in dry matter accumulation also, which was discussed elsewhere. This variation may be due to the severity of competition. Shetty and Gill (1974)

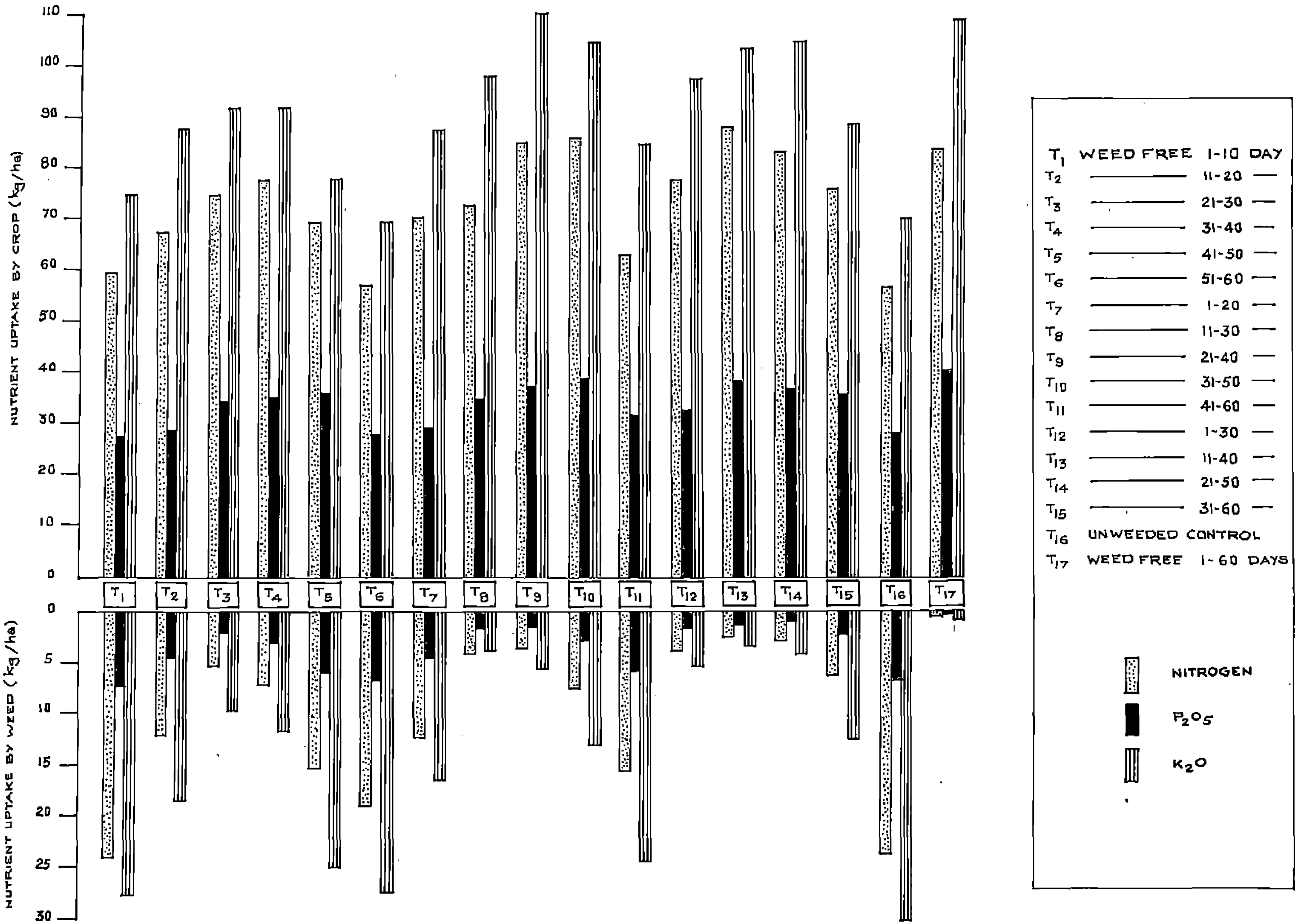


FIG. 7. TOTAL NUTRIENT UPTAKE BY CROP AND WEED AS AFFECTED BY WEED FREE PERIODS.

also got similar results with regard to nutrient uptake by crop and weed.

In general weeding before 20th and after 40th day resulted in higher uptake of N, P_2O_5 and K_2O by weed and lower uptake by crop. Therefore weeding may be done between 21-40 days for higher uptake of N and P_2O_5 and between 11-40 for higher uptake of K_2O by crop.

Verma and Mani (1970), Chakraborthy (1973), Mani (1975), Balu (1977) and Kakati and Mani (1977) all observed that weeds removed substantial quantities of nutrients when left unweeded and physical or chemical weeding improved the nutrient uptake by crop.

From the rate of removal of individual nutrients by both the crop and weed it may be concluded that the demand was maximum for K_2O followed by N and P_2O_5. Many workers like Mukhopadayay (1965), Shetty and Gill (1974) and Kakati and Mani (1977) got similar trend with regard to nutrient uptake by crop. Sankaran et al. (1974), Shetty and Gill (1974), Mani (1975) and Sankaran and Mani (1975) observed similar trend with regard to nutrient uptake by weeds in rice.

C. Protein content of grain

In general higher percentage of protein was noted in those plots in which there were less weeds during the critical

... periods of weed growth ie. 21-40 days, compared to plots weed infested during the same period. The maximum percentage of protein (8.61) was noticed in plots weeded 1-60 and 11-30 days after transplanting. The minimum protein percentage recorded was 7.34 in plot weeded 41-60 days which was on par with weedy check (7.48%). The higher protein content might have resulted from higher nitrogen uptake by weeds. Sankaran and Mani (1975) got similar results in sorghum.

Ramamoorthy et al. (1974) and Ravindran (1976) found that percentage of protein increased in hand weeded plots compared to weedy plots. Gomes and Datta (1975) were also of the opinion that weed control could improve the protein content of grain.

V. Correlation Studies

Dry matter production by weeds were negatively correlated with dry matter production by crop and grain yield. The reduction in grain yield per kg of weed dry matter was 0.605 kg/ha in weedy check. Sankaran and Mani (1975) got similar results in sorghum.

Subba Rao (1966), Anon (1974) and Rethinam and Sankaran (1974) got similar relationship with regard to dry matter production of rice and weeds. Ghosh and Pande (1967), Anon (1968), Noda *et al.* (1968), Verma and Mani (1970), Ravindran (1976) and Sharma *et al.* (1977) got negative correlation between grain yield and dry matter of weeds.

Nutrient uptake by crop (N, P_2O_5 and K_2O) were positively correlated with grain yield and negatively with weed dry matter production (Fig. 8a). As the weed dry matter accumulation increased the nutrient uptake by crop decreased and hence the grain yield also decreased.

The nutrient uptake by weeds (N, P_2O_5 and K_2O) were negatively correlated with grain yield. (Fig. 8c). Grain yield reduction per kg of N, P_2O_5 and K_2O absorbed by weeds in unweeded check were 39.15, 117.91 and 30.61 kg/ha respectively.

Okafor and Datta (1976) and Ravindran (1976) got negative correlation with N uptake by weed and grain yield. Balu (1977) also got an inverse relationship with grain yield and nutrient uptake (N, P and K) by weed.

The N, P_2O_5 and K_2O uptake by weed were negatively correlated with N, P_2O_5 and K_2O uptake by crop. From Fig. 7, it may be noted that as the weeds absorbed more of nutrients the crop uptake was reduced. The N, P_2O_5 and K_2O uptake by weeds constituted 29.48, 21.77 and 30.32 per cents of the

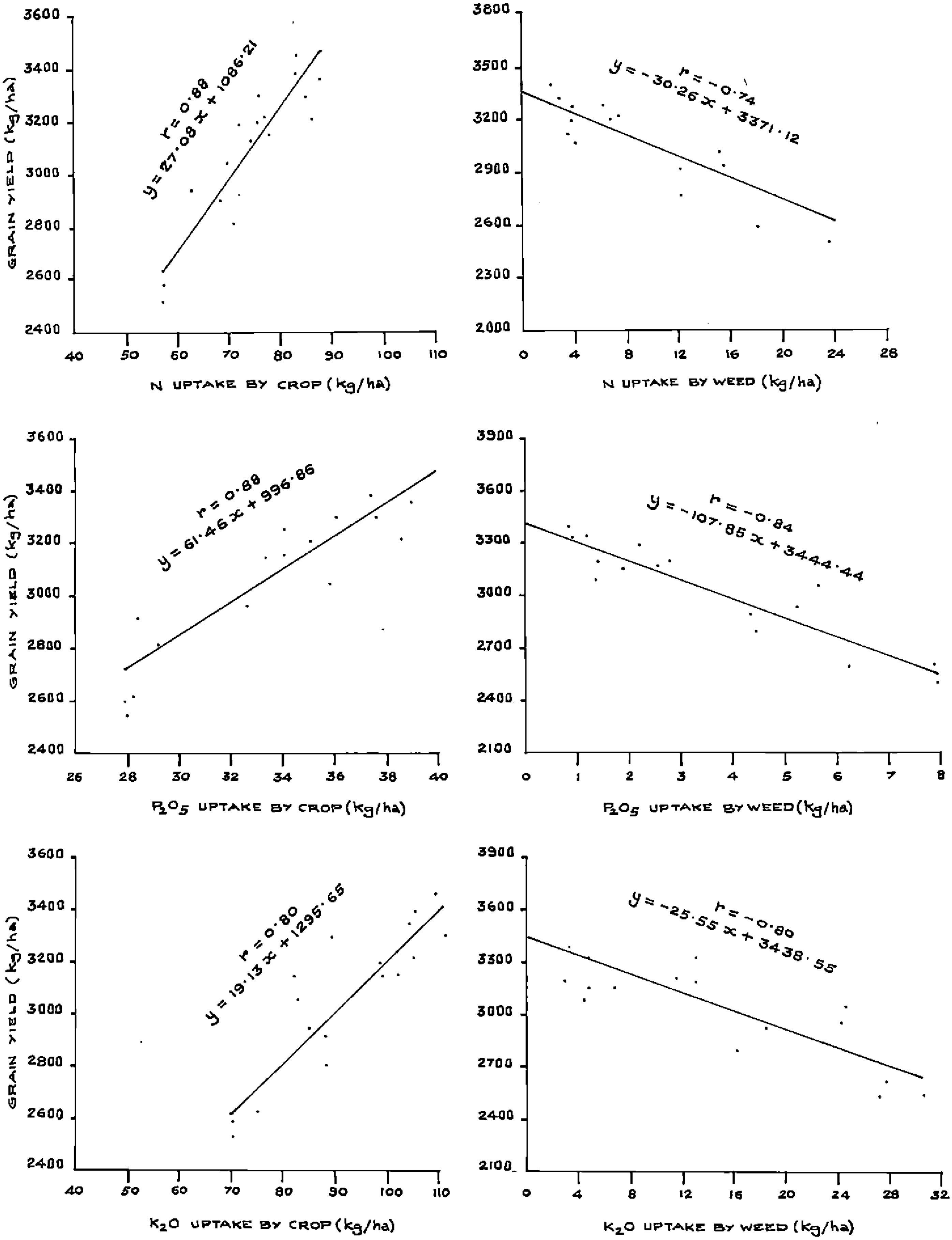


FIG. 8a. LINEAR REGRESSION OF NUTRIENT UPTAKE BY CROP AND WEED ON GRAIN YIELD.

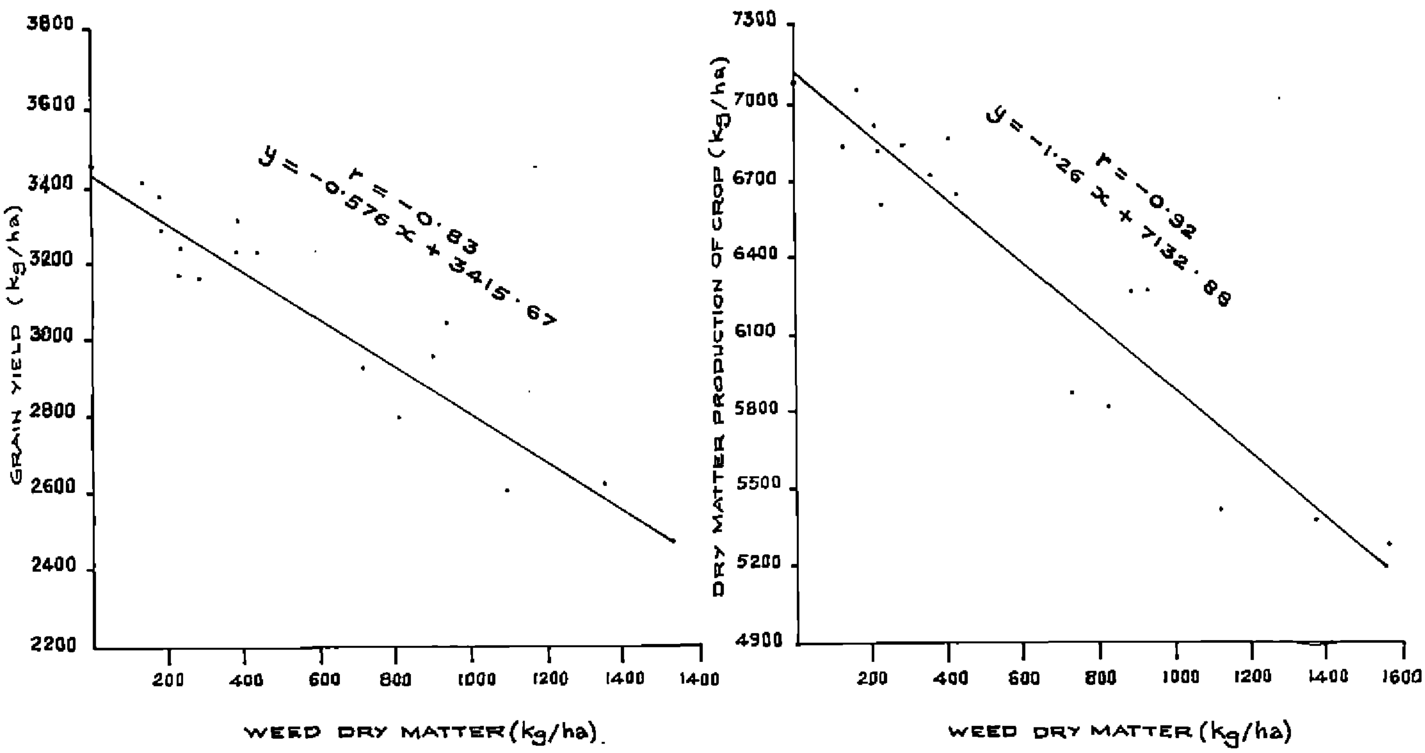


FIG. LINEAR REGRESSION OF WEED DRYMATTER ON GRAIN YIELD AND CROP DRYMATTER PRODUCTION

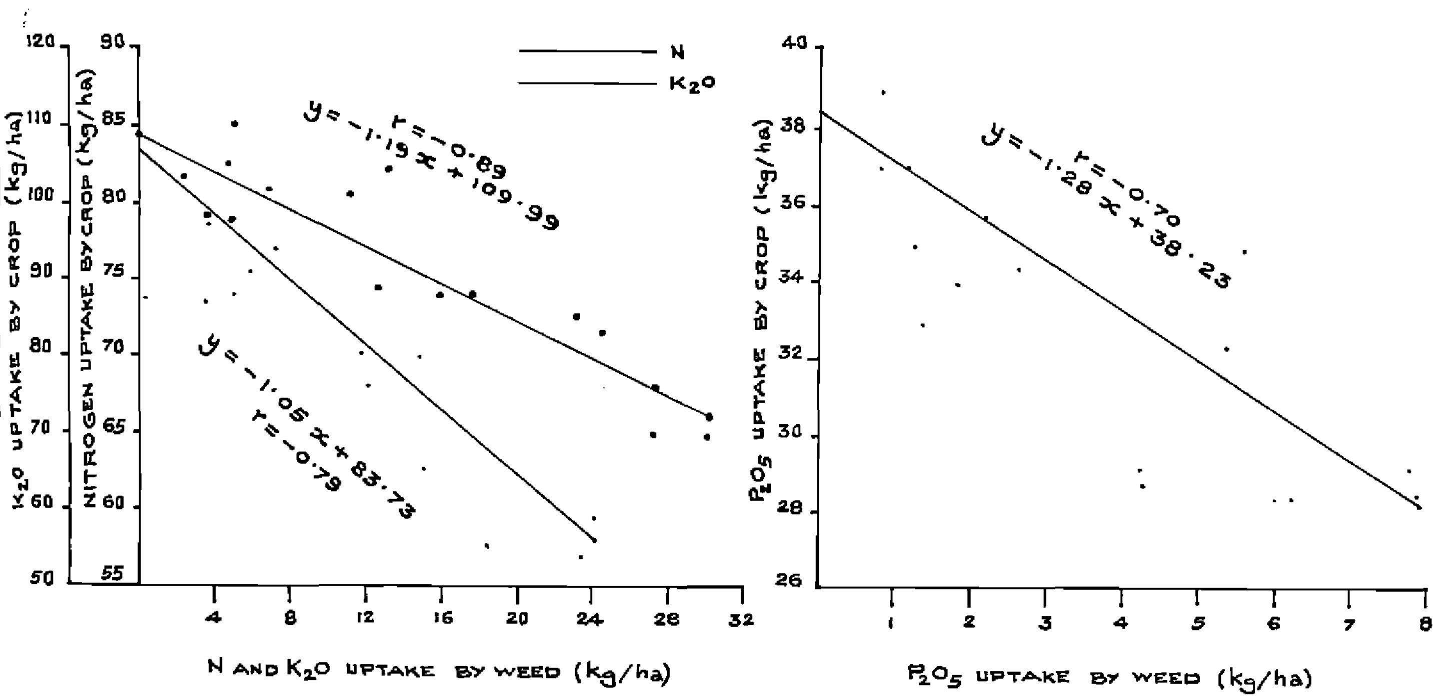


FIG. LINEAR REGRESSION OF NUTRIENT UPTAKE BY WEED ON CROP total removal of each nutrient by crop plus weed in unweeded check and were able to reduce the crop uptake by 26.17, 11.97 and 39.42 kg/ha of N, P_2O_5 and K_2O respectively, compared to plot weeded 1-60 days.

Mallappa (1973) and Ravindran (1976) got inverse relationship between N uptake by crop and N uptake by weed. Sankaran and Mani (1975) got significant negative correlation with N, P_2O_5 and K_2O uptake by sorghum and weed.

SUMMARY

SUMMARY

An experiment was conducted in the Instructional Farm attached to the College of Agriculture, Vellayani, Kerala Agricultural University, during the second crop season of 1976-'77 to study the critical periods of weed infestation and the effect of weed growth on the yield and quality of a short duration rice.

Weed characters such as weed species number of monocots, dicots and total weeds and dry weight of weeds were studied. Crop growth characters yield attributing characters and yield of grain and straw were also observed and recorded. Uptake of N, P_2O_5 and K_2O by crop and weed and protein content of grain were determined.

Correlations between important crop and weed characters were also worked out.

1. Grasses such as *Echinochloa crusgalli*, *Echinochloa colonum*, *Brachiaria ramosa*, *Ischaemum rugosum* and *Panicum* spp., sedges such as *Cyperus* spp. and *Fimbristylis milliacea* and broad-leafed weeds such as *Monochoria vaginalis* and *Ludwigia parviflora* competed with the rice crop.

2. Majority of the monocot, dicot and total weeds emerged during 11-40 days after transplanting when undisturbed

and the percentage of weed emergence was maximum during 21-30 days for dicots and 31-40 days for monocots and total weeds.

3. The maximum post-weeding emergence was during 11-40 days after transplanting for monocots and 11-30 days for dicots and total weeds.

4. Among the shortest weed free interval of 10 days tried weeding 31-40 days after transplanting reduced monocot weed population to the minimum; 11-20 for dicots and 21-30 for total weeds. Weeding 11-40 days produced least weed number (68.0/m^2) among the 10, 20 and 30 day weed free intervals tried.

5. On the 20th day of transplanting the dicot and monocot weeds were 62.35 and 37.65 per cent and at harvest they were 43.53 and 56.47 per cents of the total weed respectively in unweeded control.

6. Monocot weeds were better competitors in rice fields compared to dicot weeds, during the later stages of the crop.

7. Dry matter production by weeds upto 20th day was negligible and it increased significantly during 21-40 days with maximum accumulation during 31-40 days, reaching 154.18 g/m^2 at harvest.

8. Plots weeded 21-30, 21-40 and 21-50 days produced minimum dry matter by weeds among the 10, 20 and 30 day weed free intervals respectively.

9. Crop growth characters such as plant height, tillering and leaf area index were not significantly affected by different weed free periods.

10. Plots weeded during 11-40 days with minimum 10 day intervals generally produced more number and percentage of productive tillers in rice.

11. Weeding 21-40 days for a minimum of 10 days produced higher number of spikelets and filled grains per panicle and more weight per panicle.

12. Percentage fertility and 1000 grain weight were unaffected by weed free periods.

13. The highest grain yield of 3466 kg/ha was recorded in plot weeded 1-60 days. Whole season weed growth reduced the yield by 26.91 per cent compared to the maximum. Maximum grain yield reduction due to weed competition occured between 21st and 50th day of transplanting. The crop was able to withstand weed competition during 1-20 days and from weeds emerging after 40th day.

14. Among the 10, 20 and 30 day weed free intervals tried, 21-30, 21-40 and 21-50 days recorded the highest yields for the respective groups and were on par with the maximum obtained in plot weeded 1-60 days. Since significant weed competition began by 21st day of transplanting, weeding may be started from 21st day for ~~higher yields~~ convenience. The shortest weed free period may be between 21st and 30th day after transplanting.

15. Straw yields were generally higher in plots weeded during 21-40 days for a minimum of 10 days. Maximum straw yield of 3658 kg/ha was obtained from

the plot weeded 11-40 days and the minimum 2756 kg/ha in weedy check.

16. The maximum weed index of 25.47 was noticed in weedy check while the least index was in plot weeded 11-40 days (0.78).

17. The N, P_2O_5 and K_2O uptake by weeds were significant during 21-40 days after transplanting and the uptake was maximum during 31-40 days. Uptake of K_2O was considerable during 11-20 days also.

18. The weeds removed 23.99, 7.91 and 30.48 kg/ha of N, P_2O_5 and K_2O while the corresponding nutrient removal by crop were 57.54, 28.44 and 70.04 kg/ha in the unweeded control. The nutrients removed by crop in plot having minimum weeds (weeded 1-60 days) were 83.73, 40.41 and 109.46 kg/ha of N, P_2O_5 and K_2O respectively. The total uptake of each nutrient by crop plus weed in unweeded control was less than that by the crop alone in plot weeded 1-60 days.

19. The competition for N and P_2O_5 by crop and weed, started by 20th day of transplanting, whereas competition for K_2O started as early as 11th day of transplanting. The demand for nutrients was in the order K_2O, N and P_2O_5 by both crop and weeds.

20. Higher protein percentages of 7.92 to 8.61 were recorded in plots weeded for a minimum of 10 days between 21-40 days.

21. The dry matter production of weeds were negatively correlated with grain yield and crop dry matter production.

22. The N, P_2O_5 and K_2O uptake by weed were negatively correlated with grain yield. N, P_2O_5 and K_2O uptake by weed and crop were negatively correlated. Nutrient uptake by crop were positively correlated with grain yield and negatively with weed dry matter production.

From the investigations conducted it may be concluded that for a short duration rice variety transplanted during the second crop season under Kerala conditions, the critical period of weed competition lies between 21st to 40th day of transplanting. During this period the total weed population, dry matter accumulation and nutrient uptake by the weeds were maximum and might have affected the grain and straw yield of the crop.

Future line of work

In the light of the present study, time of application and the duration of toxicity of herbicides in the field require detailed investigation. Further studies may be undertaken by shortening the intervals of weed free days so that the exact date for weeding can be fixed.

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* Original not seen.

APPENDICES

A P P E N D I X   I

Weather data during October 1976 to January 1977 and its variation from the past 5 year's.

Weeks	Periods	Rainfall (cm)		Temperature °C Maximum	
		1976-77	Variation	1976-77	Variation
1	Oct. 3 - Oct. 9	3.71	- 0.21	30.71	+ 0.22
2	" 10 - " 16	2.71	- 1.66	30.14	+ 0.13
3	" 17 - " 23	4.00	-15.27	30.57	+ 1.79
4	" 24 - " 30	-	- 5.76	31.14	+ 1.19
5	" 31 - Nov. 6	-	-13.39	30.57	+ 0.65
6	Nov. 7 - " 13	1.85	- 3.11	30.28	+ 0.23
7	" 14 - " 20	41.71	+40.11	30.14	- 0.22
8	" 21 - " 27	0.57	- 3.20	30.42	-
9	" 28 - Dec. 4	7.28	+ 4.16	30.00	-0.50
10	Dec. 5 - " 11	1.00	- 2.38	30.71	+ 0.21
11	" 12 - " 18	0.42	- 4.09	31.28	+ 1.02
12	" 19 - " 25	-	- 1.80	31.71	+ 1.49
13	" 26 - Jan. 1	0.57	+ 0.09	30.85	+ 0.57
14	Jan. 2 - " 8	-	- 0.31	31.00	+ 0.43
15	" 9 - " 15	-	-	30.85	+ 0.08
16	" 16 - " 22	-	- 1.08	31.12	+ 0.42
17	" 23 - " 29	-	- 0.62	31.54	+ 0.74
18	" 30 - Feb.5	-	- 0.20	30.57	- 0.63

+ more than 5 years' data
- less than 5 yearsd data

Contd.....2...

APPENDIX I

Weather data during October 1976 to January 1977 and its variation from the past 5 years'.

Weeks	Periods	Temperature °c Minimum		Relative humidity (%)	
		1976-77	Variation	1976-77	Variation
1	Oct. 3 - Oct. 9	23.42	-0.36	87.15	+4.11
2	Oct. 10 - Oct. 16	23.14	-0.21	87.72	+5.00
3	Oct. 17 - Oct. 23	23.00	+0.10	84.86	-0.01
4	Oct. 24 - Oct. 30	23.42	+0.19	80.14	-8.32
5.	Oct. 31 - Nov. 6	23.00	-0.30	82.57	-1.34
6	Nov. 7 - Nov. 13	23.00	-0.02	88.29	+5.21
7	Nov 14 - Nov. 20	23.14	+0.09	91.42	+9.75
8	Nov 21 - Nov. 27	23.57	-0.10	85.57	+1.37
9	Nov 28 - Dec. 4	23.42	+0.82	88.58	+5.69
10	Dec. 5 - Dec. 11	22.57	+0.28	81.28	+1.72
11	Dec. 12 - Dec. 18	23.14	+1.33	76.85	-2.67
12	Dec. 19 - Dec. 25	23.85	+1.80	78.57	+0.81
13	Dec. 26 - Jan. 1	21.57	-1.15	76.57	-1.48
14	Jan. 2 - Jan. 8	21.37	-0.27	71.57	-5.61
15	Jan. 9 - Jan. 15	21.15	-1.11	67.58	-8.69
16	Jan. 16 - Jan. 22	20.45	-1.51	65.00	-10.26
17	Jan. 23 - Jan. 29	22.72	+0.57	76.57	+ 0.62
18	Jan. 30 - Feb. 5	22.12	+0.36	73.42	- 1.13

+ more than 5 years' data
- less than 5 years' data

APPENDIX II

Summary of the analysis of variance tables for weed population/M^2

Source	d.f.	Mean Squares		d.f.	Mean squares
		Pre-weeding.	10 days after weeding		At harvest
Monocot weed population					
Total	23			33	
Block	1	0.451	0.513	1	0.131
Treatment	11	71.928**	3.911**	16	63.034**
Error	11	0.635	0.457	16	0.654
Dicot weed population					
Total	23			33	
Block	1	0.462	0.031	1	0.239
Treatment	11	92.103**	13.203**	16	39.836**
Error	11	0.539	0.187	16	0.122
Total weed population					
Total	23			33	
Block	1	1.084	0.280	1	0.344
Treatment	11	167.335**	14.932**	16	103.213**
Error	11	0.578	0.523	16	0.744

** Significant at 0.01 level.

Note: Data analysed after square root transformation.

APPENDIX III

Summary of the analysis of variance tables for the dry weight of weeds

Source	d.f.	Mean squares Pre-weeding ($g/0.54\ m^2$)	d.f.	Mean squares At harvest ($g/0.54\ m^2$)	Mean squares Total (g/m^2)
Total	23		33		
Block	1	13.590	1	12.000	6.442
Treatment	11	875.013**	16	1319.025**	4278.056**
Error	11	24.321	16	11.373	109.605

** Significant at 0.01 level.

APPENDIX IV

Summary of analysis of variance tables for the height of plants (cm) at different days after transplanting (D.A.T.)

Source	d.f.	Mean squares						
		10 D.A.T.	20 D.A.T.	30 D.A.T.	40 D.A.T.	50 D.A.T.	60 D.A.T.	At harvest
Total	33							
Block	1	36.732*	72.474	219.197**	375.620**	231.240**	189.350**	119.270*
Treatment	16	9.672	4.599	10.008	9.946	18.934	11.293	10.620
Error	16	7.836	18.376	17.287	16.391	21.098	20.374	19.460

* Significant at 0.05 level.

** Significant at 0.01 level.

APPENDIX V

Summary of the analysis of variance tables for the tiller numbers/hill at different days after transplanting (D.A.T.)

Source	d.f.	Mean squares				
		10 D.A.T.	20 D.A.T.	30 D.A.T.	40 D.A.T.	At harvest
Total	33					
Block	1	0.003	0.095	0.220	0.664	0.460
Treatment	16	0.320	0.535	0.661	0.382	0.283
Error	16	0.282	4.484	0.803	0.611	0.151

APPENDIX VI

Summary of analysis of variance tables for the leaf area index at different days after transplanting (D.A.T.)

Source	d.f.	Mean Squares				
		20 D.A.T.	30 D.A.T.	40 D.A.T.	50 D.A.T.	60 D.A.T.
Total	33					
Block	1	0.235	0.077	0.842	2.260	0.220
Treatment	16	0.486	1.435	0.768	0.358	0.610
Error	16	0.776	1.967	1.345	24.280	0.710

APPENDIX VII

Summary of analysis of variance tables for productive tillers and percentage of productive tillers.

Source	d.f.	Mean Squares	
		Number of productive tillers/m^2	Percentage of productive tillers.
Total	33		
Block	1	512.470	39.120
Treatment	16	2435.250**	38.141*
Error	16	639.280	14.650

* Significant at 0.05 level.

** Significant at 0.01 level.

Note: Data on percentage of productive tiller analysed after angular transformation.

APPENDIX VIII

Summary of the analysis of variance tables for panicle characters

Source	d.f.	Mean squares				
		Length of panicle (cm)	Weight of panicle (g)	No. of spikelets per panicle	No. of filled grains per panicle.	Percentage of filled grains.
Total	33					
Block	1	0.002	0.055	59.560	173.530**	13.460
Treatment	16	1.423	0.097**	119.055*	81.066**	12.737
Error	16	1.336	0.017	43.621	18.530	10.818

* Significant at 0.05 level.

** Significant at 0.01 level.

Note: Data on percentage of filled grain analysed after angular transformation.

APPENDIX IX

Summary of the analysis of variance tables for yield characters

Source	d.f.	Mean squares		
		100 grain weight (g)	Grain yield (kg/15.12 m^2)	Straw yield (kg/15.12 m^2)
Total	33			
Block	1	0.790	0.610**	0.106
Treatment	16	0.065	0.396 **	0.509**
Error	16	0.545	0.054	0.024

** Significant at 0.01 level.

APPENDIX X

Summary of the analysis of variance tables for nutrient uptake by weeds.

Source	d.f.	Mean squares Pre-weeding (g/0.54 m^2)	d.f.	Mean squares At harvest (g/0.54 m^2)	Total (kg/ha)
		Nitrogen			
Total	23		33		
Block	1	356.973	1	975.094 *	5.960
Treatment	11	2425.604**	16	3457.864**	114.560**
Error	11	136.744	16	214.700	12.850
		Phosphorous		(P_2O_5)	
Total	23		33		
Block	1	17.767	1	8.171	1.500*
Treatment	11	294.073**	16	380.527**	12.490**
Error	11	7.837	16	5.036	0.330
		Potassium		(K_2O)	
Total	23		33		
Block	1	1101.073 *	1	0.137	27.420
Treatment	11	5790.308**	16	5537.810**	197.210**
Error	11	279.336	16	31.633	8.630

* Significant at 0.05 level.

** Significant at 0.01 level.

APPENDIX XI

Summary of the analysis of variance tables for the total nutrient uptake by crop at harvest kg/15.12 m^2 and protein content of grain (%)

Source	d.f.	Mean Squares			
		Nitrogen	P_2O_5	K_2O	Percentage of protein
Total	33				
Block	1	0.000100	0.000100*	0.000054	1.652**
Treatment	16	0.000463**	0.000081**	0.000815 **	0.347*
Error	16	0.000044	0.000013	0.000036	0.148

* Significant at 0.05 level.

** Significant at 0.01 level.

STUDIES ON THE CRITICAL PERIODS OF WEED INFESTATION AND EFFECT OF WEED GROWTH ON YIELD AND QUALITY OF A SHORT DURATION RICE

BY

ABRAHAM VARUGHESE

ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENT FOR THE

MASTER OF SCIENCE IN AGRICULTURE

FACULTY OF AGRICULTURE

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

VELLAYANI - TRIVANDRUM

1978

ABSTRACT

Studies on the critical periods of weed infestation and effect of weed growth on yield and quality of a short duration rice.

An experiment was conducted at the Instructional Farm of the College of Agriculture, Vellayani, Kerala Agricultural University during the second crop season, 1976-'77 to study the critical periods of weed infestation and effect of weed growth on the yield and quality of a short duration rice var. Triveni.

Simple randomised block design was adopted with 17 treatments. Hand weeding was done to keep weed free conditions of 10, 20 and 30 day intervals upto 60th day and for 1-60 days after transplanting. The above weed free periods with one unweeded control formed the 17 treatments.

Monocot weeds were found to be better competitors compared to dicot weeds. The weed establishment in number was maximum during 11-40 days after transplanting, whereas the critical period of dry matter accumulation was 21-40 days. Weed growth was most critical during 31-40 days.

Weed competition did not affect plant height, tiller number and leaf area index of rice. Number and percentage

of productive tillers, number of spikelets and filled grains per panicle and panicle weight were affected by weeds, whereas length of panicle, percentage fertility and 1000 grain weight were unaffected.

The grain yield suffered maximum from weed competition between 21st to 50th day after transplanting. Whereas the crop was able to withstand weed competition 1-20 days as well as from those emerging after 40th day of transplanting. The maximum grain yield of 3466 kg/ha was recorded in plot weeded 1-60 days and whole season competition reduced yield by 26.91 per cent. Weeding need be started by 21st day of transplanting and the shortest weed free period which produced maximum yield as good as the highest yield was 21-30 days.

The maximum weed index (25.47) was in unweeded check and the minimum in plot weeded 11-40 days (0.78).

The N, P_2O_5 and K_2O uptake by weeds was critical during 21-40 days. The weeds in weedy check removed 23.99, 7.92 and 30.48 kg/ha of N, P_2O_5 and K_2O, and the crop removed 57.54, 28.41 and 70.04 kg/ha of the corresponding nutrients. Crop uptake of N, P_2O_5 and K_2O from plot weeded 1-60 days were 83.73, 40.41 and 109.46 kg/ha respectively. Competition for N and P_2O_5 began from 21st day onwards whereas for K_2O was started by 11th day after transplanting.

The demand was maximum in the order of K_2O, N and P_2O_5 by both crop and weed. Weed free conditions increased the protein content of grain from 7.34 to 8.61 per cent.

There were highly significant correlations between weed dry matter and crop dry matter (-ve), weed dry matter and grain yield (-ve), nutrient uptake by crop (N, P_2O_5 and K_2O) and grain yield (+ve), nutrient uptake by crop and weed dry matter (-ve), nutrient uptake by weed (N, P_2O_5 and K_2O) and grain yield (-ve) and nutrient uptake by weed and crop (-ve).