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EVALUATION OF SELECTIVE HERBICIDES AND CULTURAL METHODS FOR WEED CONTROL IN IRRIGATED SORGHUM (*Sorghum vulgare* Pers.)

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INTRODUCTION

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Weed science involves the study and control of the more aggressive, troublesome and undesirable plants of the world's vegetation and it has made a significant contribution to the science of crop production. Moore (1954) defined weed as 'a plant which interferes with man's utilization of land for a specific purpose'.

Crop growth may be retarded by competition of associated weeds for the essential growth factors of light, moisture and plant nutrients. The taller, sturdy or more numerous the weeds in relation to the crop, the stronger is the competition. Most of the weeds are vigorous feeders of moisture and plant nutrients, and by their aggressive nature they starve out the crop plants. Shading by weeds results in stunted and unhealthy plants which eventually get destroyed.

Unchecked growth of weeds in association with the crop results in partial or complete loss of yield. Verma and Lambo (1962) reported an estimated loss in yield due to weed infestation ranging from 10 to 80 per cent depending on the crop, the weed species and the intensity of their infestation. Smith and Shaw (1966) found infestation of Echinochloa species at the rate of one and five plants per square foot to reduce the yield of rice by 18 and 36 per cent respectively. Panicker (1961) estimated an annual loss in yield of 11.43 million tons, costing about 1,620 million rupees due to

weeds in rice, wheat, maize, jowar, bajra and sugarcane in India. Sabins and Pathak (1962) reported a loss of 3,700 million rupees due to weeds in all crops grown in India. Shepard and Mahan (1965) estimated an annual loss of 5,116 million dollars from weed infestation in United States. Hence, the importance of weed control need hardly be emphasised.

As man took up agriculture in the primitive world, the early attempt on crop production must have been associated with weeding, first perhaps by pulling out to prepare the seed bed, later by cutting or hoeing or cultivation with primitive implements. So, weed control or elimination of a plant out of place is as old as agriculture. This has ever remained with him and has become a dominant factor in modern crop production.

The realisation that weeds compete with crops lead to the evolution of various weed control techniques. Use of hand tools and implements, special practices like flooding, mulching and flaming and use of insects and fungi are some of the weed control methods that followed. Though efficient, these methods were laborious, time consuming and not easy to adopt in large farms. Search for easier, efficient and more practicable methods continued, which lead to the discovery of weed killing property of some chemicals.

Chemical method of killing weeds began nearly seventy years ago, when Bonnet in France showed in 1896, that a solution of copper sulphate would kill charlock plants growing with cereals.

Bolley (1908) from North Dakota reported successful weed control in wheat using table salt, iron sulphate, copper sulphate and sodium arsenite. Pokorny (1941) in United States reported synthesis of 2,4-D and Zimmerman and Hitchcock (1942) reported the growth regulator property of 2,4-D. Martha and Mitchel (1944) established selectivity of 2,4-D by controlling dandelion, plantain and other broad leaved weeds from a blue grass lawn. Harner and Tuke (1944) described successful field trials of 2,4-D as a herbicide. Templeman (1945) established the pre-emergence principle of soil treatment for selective weed control.

Research during the past four decades has lead to the development of a variety of chemicals and new techniques for the control of weeds. Most of these chemicals were non-poisonous, easy to handle, highly selective in their action and were needed only in small quantities to kill a wide range of weeds. Chemical weed control can be adopted even in time and situations which present difficulties to mechanical weeding. This method is easier, less time consuming and less costly than weeding by manual labour. Large number of selective herbicides developed in the past decade could solve specific weed problem in different crops. Therefore, to use the technique of selective weed control in crops one must know the crop in which it can be used the weeds that will be destroyed and above all the minimum dose that should be applied to obtain the maximum kill of weeds with least or no injury to the crop.

Chamberlain et al. (1967) have found that a rate of four pounds active ingredient of atrazine has significantly reduced sorghum yield on a six inches tall crop while one and two pounds rates had no effect. Similarly yields on a one and three inches tall sorghum was affected by applications of atrazine from one to four pounds whereas a 12 inches tall sorghum was not affected by applications up to four pounds per acre. To be successful in selective weed control it is essential to determine the best herbicide and best time of application for each crop under different situations of soil, climate and cultivation practices.

Some of the herbicides developed recently such as atrazine and simazine by Geigy Basle (1959) and ramrod by Monsanto chemicals, Missouri (1964) are reported to be selective in maize, sorghum and legumes with good herbicidal property. Krishna Rao et al. (1951), Anon. (1959), Verma (1963) and Bodade (1965) have all reported significant increases in grain yield of sorghum due to adoption of various methods of weed control. But efficiently of the latest chemicals as a selective herbicide on sorghum under Coimbatore conditions has not been studied.

Sorghum is an important grain crop of Madras, Maharashtra, Gujarat, Madhya Pradesh and Rajasthan. As a fodder crop, it is grown practically in all parts of India. The crop occupies an area of 18 million hectares with a total production of 8.94 million tonnes of grain (Records and Statistics, 1967).

It was felt that an efficient, cheap and labour saving method of weed control, if available for sorghum, could boost up the production of this crop. Hence, the study was undertaken to develop such a method of weed control for sorghum with the following objects.

1. To choose an efficient selective herbicide for weed control in sorghum and to study its effects on the crop.

2. To compare the efficiency and economics of herbicides with the local practice of hoeing and weeding.

3. To estimate the relationship between weed growth and crop yield.

4. To study whether interculitivation could be dispensed with by the use of selective herbicides in sorghum and

5. To investigate the after effects of herbicide application.

REVIEW OF LITERATURE

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I. IMPORTANCE OF WEED CONTROL IN CROP IMPROVEMENT

Control of weeds in agricultural crops assumed considerable importance in view of the need to enhance production of food, fibre and fodder. Weeds are observed to cause tremendous loss in a silent and unnoticed manner. In many cases the loss due to the weeds has been estimated to be as high as 70 to 80 per cent (Verma et al., 1958).

In sorghum, Krishna Rao et al. (1951) observed that under dry land conditions, weed control by spraying fernoxone increased the yield by 83 per cent. From a weed control experiment at Bombay it was reported that increase in yields ranged from 84.2 to 336.7 per cent over control by adopting different methods of weed control (Anon., 1958). Chackravarthy (1961) based on the results of an experiment to study the effect of weed control on sorghum concluded that cultural methods of weeding showed the highest yield of 748 pounds per acre. Mathur (1961) reported that weed control on sorghum resulted in yield increases ranging from 103 to 187 per cent over control. Pofford and Harvey (1967) found that severe competition of pig weed in irrigated sorghum reduced the yield from 4696 pounds in the weed free plot to 794 pounds per acre in the infested plot.

Aryeetey and Khan (1966) in rice, Poignant et al. (1965) in wheat, Mathur (1961) in bajra, Vengris (1967) in maize and Puran and Adlakar (1961) in sugarcane reported increases in yield from weed control.

II. EFFECT OF WEEDS ON CROP GROWTH, PLANT CHARACTERS AND CROP YIELDS.

a) Effect of weeds on crop growth: Plants growing thickly together in an area are influenced in their growth by the presence of adjacent plants by limiting space, moisture and nutrients and in some cases by toxicity. This may result in dwarfing, starving, wilting and actual drying out of the less successful plants.

Tadulingam and Venketanarayan (1932) describing Trianthema portulacastrum, a common weed of the dry and gardenland remarked that on account of its gregarious nature and prostrate habit it became so bad in cultivated fields that the growth of any crop was almost impossible. King (1966) said that the rate at which certain species of weeds grew in height as well as in leaf area, frequently enabled them to surpass the growth of crop plants and eventually to crowd them out altogether. Thus, competition for space involves occupying spaces around or very near to the crop plant. This may be achieved by one plant, or small numbers of plants of great size and rapid growth rate or it may be achieved by very large numbers of plants possessing either moderate or rapid rates of growth.

The most serious factor limiting crop growth is competition from weeds for nutrients and moisture. Collotal et al. (1916) stated that the upper three inches soil where the weeds were permitted to grow contained only 81.6 pounds of nitrates while a comparable area with three inches mulch contained 433.3 pounds

of nitrates per acre. Asana (1951) found that unchecked weed growth in wheat removed as much as 17 pounds of nitrogen from an acre resulting in poor wheat yields. Kapoor (1960) found that pholi depleted the soil of nearly 60 pounds of nitrogen per acre. Misra and Kumar (1962) from a weed control experiment observed that at six inches soil depth the moisture in an unweeded plot was 2.5 per cent as against four per cent in the weeded plot. The difference was significant and was maintained throughout the crop growth period.

Molisch (1937) reported instances of influences of higher plants upon one another which cannot be attributed to competition for water, nutrients or space. Oswald (1947) found that heavy growth of quack grass (Agropyron repens) reduced the germination and growth of rape (Brassica napus and Brassica rapa) and termed 'Phytotoxins' for the chemical substances involved in exhibiting such effects. Wilderan (1948) used the term 'telitoxicity' for such mutual influence. Martin and Rademacher (1960) stated that for such mutual effects for which products of plant metabolism might be held responsible, the term 'allelopathy' has been used.

Martin and Rademacher (1960) from investigations on mutual influence found that potato and flax were strongly depressed when grown together with Polygnum persicaria. Holm (1965) studying mutual toxicity of plants reported that some plants such as Artemisa sp. and Salvia leucophylla were able to produce zones of inhibition extending upto 90 centimeters beyond the

shrub canopy, due to volatile inhibitors evolved from the leaves. Similarly, root exudates of Polygonum pensylvanicum cultivated on sterile floating pads of plastic foam have completely inhibited the growth of tomato root tips. Schreiber and Williams (1967) studying the toxicity of the roots of Setaria faberii and Setaria glauca found that they inhibited the root growth of maize.

b) Influence of weeds on plant characters: McRostie and Tildesley (1934) reported reduction on number of heads per plant in wheat, Blackman and Templeman (1938) found that the size of spike was reduced in barley and Bondeen and Bucholtz (1964) observed height reduction and delayed tasseling in maize due to weed competition.

Burnside and Wicks (1965) from a similar experiment reported that weedy check significantly reduced plant establishment, seed weight per head and plant height while 100-seed weight was not affected. Lapchenkov (1966) from trials on fodder sorghum using herbicides found that weed control raised the yields of fresh material.

Pafford and Harvey (1967) studying the effect of pig weed on irrigated sorghum by growing various densities of pig weed in between sorghum rows found that the grain yield of all treatments containing weed was significantly lower than that in the weed free check. Sorghum stover yields generally decreased as the pig weed density increased. Wiese (1967)

studying competition among weeds and sorghum by estimating the weight of foliage per plant found that sorghum grown with sorghum produced 2.2 grams of foliage, sorghum with tumble grass produced 3.3 grams of foliage per plant while with corn it was only 1.6 grams per plant.

c) Relationship between weed growth and crop yield:
Robinson (1949) studying the effect of annual weeds on oats, wheat and flax yields, reported that a moderate infestation of annual weeds caused significant reduction in all the crops. In wheat Riese and Davis (1962) obtained a correlation coefficient of -0.77 between the weight of tansy mustard infesting winter wheat and total dry matter of wheat and of -0.73 between the weight of tansy mustard and wheat yields. Bell and Nalewaja (1966) studying the effect of wild oats competition in cereals reported that the presence of five and 65 wild oats per square yard reduced grain yields of wheat by 2.7 and 24.5 per cent and in barley by six and 20 per cent respectively.

Dunham (1964) reported that a heavy infestation of amaranthus and chenopodium reduced yields of soyabean by more than half and maize by 20 bushels per acre. Fowson (1964) found that the infestation of one noogoorabur per square yard reduced groundnut yields by 16 per cent. Nieto (1965) observed that weed competition in the first 40 days reduced the yield of potato by 40 per cent, in maize 50 per cent and in beans by 90 per cent.

Horowitz and Kletter (1963) concluded from a weed control experiment on irrigated sorghum that the weed infestation reduced grain yields of unweeded plots of about 40 per cent. Wicse *et al.* (1964) from a long term experiment on dry land and irrigated sorghum noticed that the weed growth resulted in yield reductions from eight to 41 per cent.

Burnside *et al.* (1964) observed from a weed control experiment on dry land sorghum that the average yields indicated a loss of one bushel of grain for every 50 pounds of weeds present in an acre. Burnside and Wicks (1965) from another experiment on dry land sorghum reported that sorghum yields estimated were negatively correlated with weed yields. Correlation between straw yield and weed growth could not be traced.

III. SELECTIVE WEED CONTROL IN SORGHUM

Weed control in cereal crops using selective herbicides is successfully practised in recent times. This review enumerates the available results on the use of selective herbicides such as 2,4-D, atrazine and ramrod in relation to different methods of application for weed control in sorghum.

a) *2,4-D:* Krishna Rao *et al.* (1951) observed under dry land conditions that one spraying of 2,4-D on one month old sorghum killed the weeds. Baner Raj *et al.* (1958) reported Formoxone, Coronoxe and Altacid most effective for controlling dicot weeds. Rehudkar (1959) could completely control annual

grasses and dicot weeds by pre-emergence application of 0.2 per cent aqueus solution of 2,4-D. In the co-ordinated weed control scheme, Nagpur (Report 1955-60) a combination treatment of 2,4-D pre-emergence and post-emergence at 1.5* pounds per acre followed by cultural method proved to be effective in controlling weeds. From the results of experiments at Bombay for two years it was observed that good control of weeds were obtained with pre-emergence and post-emergence application of 2,4-D at 1.5 and one pound respectively (Anon., 1959). Dickens et al. (1967), McCormic (1967) and Gosset and Nolan (1967) have recommended post-emergence application of 2,4-D amine at 0.5 pound per acre for broad leaved weed control in sorghum.

Albert (1961) reported excellent control of broad leaved weeds from 2,4-D one pound per acre when sorghum was six and 12 inches tall and from pre-emergence application of atrazine at one to 1.6 pounds per acre without injury to sorghum. Phillips (1964) observed that use of propazine or atrazine pre-emergence or norea pre-emergence followed by 2,4-D post-emergence gave season long control of weeds. Faivre Dupaigre and Dognon (1965) reported that atrazine, 2,4-D amine or a combination of both were well tolerated by sorghum at four to five leaf stage.

Ineffectiveness of 2,4-D for selective weed control in sorghum have also been observed in some situations. Horowitz

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* The doses mentioned in this review refers to active ingredient of the chemical.

and Kletter (1963) from trials on irrigated sorghum with atrazine, propazine, prometryne and 2,4-D at different doses and methods of application concluded that atrazine one kilogram per hectare pre-emergence with or without incorporation showed considerable promise than the standard 2,4-D. Wiese et al. (1964) found that 2,4-D at 0.5 pound per acre applied to 10 inches tall sorghum caused injury and depressed yields. Kukodi (1965) from a ten years trial on sorghum reported 2,4-D was less suitable because of the short duration of its action. Lepchenkov (1966) from a trial with sodium, amine and ester formulations of 2,4-D, simazine and atrazine stated that pre-sowing applications of simazine and atrazine were the best treatments.

b) Atrazine: Smith (1963) found from pre-emergence trial in sorghum that simazine, atrazine and propazine at 2.5 pounds per acre gave excellent weed control. Pachi and Gupta (1964) from pre-emergence trial with several herbicides concluded that atrazine was very effective in controlling dicot weeds at rates as low as one pound per acre. Bovey et al. (1965) found that atrazine pre-emergence at two pounds per acre was more effective than CDAA and T.C.B.C.

Anderson (1964) reported atrazine at two pounds per acre early post-emergence gave excellent control of grass and broad leaved weeds. Burnside and Wicks (1964) found that atrazine pre-emergence at two and four pounds per acre most effective on non-cultivated plots giving yields equivalent to hand weeded

plots. Philips (1965) reported that atrazine at three pounds per acre gave excellent control of weeds. Bodade (1965) from a trial with trazines, randox-T, dalapon and 2,4-D found that atrazine at 0.85 and 1.7 kilogram per hectare was the best among all treatments.

Phillips (1964) applied atrazine at three pounds per acre to wheat subbles shortly after harvest and was able to raise a normal weed free crop of sorghum in the following year. Morowitz (1964) reported spraying the atrazine or propazine at 1.5 kilogram per hectare to the winter fallow effected good control of weeds in the succeeding sorghum upto harvest.

Arle (1962) reported 95 to 100 per cent control of a dense infestation of Echinochloa cruscalli by atrazine at four pounds per acre applied to sorghum at the three leaf stage. Faivre Dupaigre (1963) from pre-emergence and post-emergence trials with simazine and atrazine concluded that atrazine at two kilograms per hectare is more safe at the three leaf stage. Phillips and Ross (1965) from a trial on ten grain sorghum hybrids found that atrazine three pounds applied post-emergence on three to five inches tall sorghum gave excellent control of weeds.

Chamberlain et al. (1967) studying the effect of different rates of atrazine at different stages of growth concluded that a significant increase in yield over hand weeded check was obtained when atrazine was applied at the rate of one pound per acre on six inches tall sorghum. Williams et al. (1967) from pre plant, pre-emergence and post-emergence application

of atrazine, propazine and G.S.14260 concluded that for post-emergence application of atrazine at one and 1.5 pound per acre was safe and effective at the six inches stage.

Burnside et al. (1964) found that a combination of tillage, narrow row spacing and pre-emergence application of atrazine at one pound per acre gave more dependable weed control. Stickler and Anderson (1964) studying the effect of various doses of triazines on 20 and 40 inches rows concluded that atrazine at 0.5 pounds per acre applied pre-emergence or early post-emergence in conjunction with narrow row spacings will provide adequate season long control of weeds.

For weed control in sorghum Gosset and Nolan (1967) recommended pre-emergence application of atrazine at two pounds per acre. Lewis and Worsham (1966), Nester and Harold (1967), Miller and Hogan (1967), Herron and Philips (1967) and Greer (1967) have recommended early post-emergence application of atrazine at the rate of two to three pounds per acre.

c) Ramrod: Stroube (1967) observed that ramrod has given excellent control of annual grasses and fair to good control of broad leaf weeds in corn. McKie et al. (1967) observed herbicidal property of ramrod in legumes. However, Burnside and Robison (1967) from a herbicide trial conducted on sorghum in 27 locations reported that ramrod showed the least control of weeds.

IV. EFFECT OF HERBICIDE ON THE CROP WHEN APPLIED FOR WEED CONTROL

The selectivity of herbicides on the crop is evaluated by testing and trial under varied situations. Such investigations have brought to light selectivity of several herbicides on different crops under different times, rates and methods of application. But certain cases of crop injury and stimulation of growth attributes of the crop has also been reported by several workers, which may help to avoid such injury to crop and to arrive at a safe range of selectivity for different crops. Some of the reported instances of direct effect of herbicides on the crop are reviewed.

Fischer et al. (1966) found that if plumule of rice emerged through soil treated with ordram the stand and vigour of the crop was adversely affected. Freisen (1965) reported that picloram applied to wheat later than the six leaf stage reduced wheat yields. Dubrowin and Gull (1966) stated that cypromide spray was selective on maize when prevented from contact with the upper portion of the plant. Kulkarny (1959) treated sets of sugarcane with 2,4-D and obtained better germination and vigourous shoot.

Nahudker (1959) from pre-emergence application of 2,4-D at 0.2 per cent to sorghum observed significant reduction of plant height and to some extent leaf number. Albert (1961) reported that sorghum did not tolerate pre-emergence application of EPTC, Naptolam and 2,4-DEP at rates normally sufficient to give weed control. Simazine at one to 1.6 pounds rate injured

sorghum. Arle (1962) observed slight temporary growth check and chlorosis of sorghum following a pre-emergence application of propazine at four pounds per acre.

Phillips and Rose (1962) found that flowering of a crop treated with propazine pre-emergence or atrazine post-emergence was advanced by a few days and plant height slightly exceeded those of the cultivated controls. In another trial on 60 strains of sorghum with propazine at six pounds and atrazine at three pounds per acre pre-emergence caused severe stunting and reduction of stand respectively. Burnside et al. (1964) reported that atrazine application increased the number of heads per plant weight of individual heads and yield compared with untreated controls, but resulted in decrease in the yield of fresh material, plant density and bushel weight. Wiese et al. (1964) reported that when 2,4-D was applied at 0.5 pounds per acre to 10 inches tall sorghum it caused injury and depressed grain yields.

Bodade (1965) reported that simazine and 2,4-D depressed plant height and 2,4-D and dalapon resulted in injury to sorghum. Burnside and Wicks (1965) from an experiment with herbicides and cultural practices observed that CDAA plus TCBC treatment reduced plant height and significantly reduced germination of sorghum seed below hand weeded control. Khuspe et al. (1966) studying the effect of soil applied atrazine on growth of sorghum observed significant difference in dry matter production on the 30th day after sowing, but at ear emergence the differences were not

significant. Sciffers and Santelmann (1966) studying the response of sorghum to post-emergence application of paraquat found that the 13 varieties tested showed various degrees of leaf and sheath burn, but none showed a significant reduction in yield when the plants were taller than six inches.

Chamberlain et al. (1967) observed that rates of half, one and two pounds atrazine sprayed on one, three and six inches tall sorghum grown on a loam sand showed yield reductions at all the three stages of growth. In another trial when one, two and four pounds per acre rate was applied on one, three, six and 12 inches tall sorghum the one and three inches tall sorghum showed significant yield reductions. Williams et al. (1967) reported that pre-emergence application of propazine and G.S.14260 caused only light crop injury whereas G.S.13528 caused 38 per cent reduction in stand and G.S.14253 caused 69 per cent reduction of stand with moderate injury. In another trial with atrazine at 0.5 and 1.5 pounds applied pre-plant caused 10, 20 and 30 per cent injury respectively over the check. George et al. (1967) investigating the effect of post-emergence application of atrazine at 2.7 kilogram per hectare on five varieties of sorghum found that the height of sorghum was significantly increased over the cultivated control, none of the other characters studied showed significant difference.

V. ROLE OF INTERCULTURE

Earlier concept on cultivation was that it conserved soil moisture. King (1907) emphasised the necessity of maintaining a dust mulch for controlling moisture loss. The report of Bureau of Plant Industry (1913) of the United States Department of Agriculture, based on 125 experiments with maize over 28 states stated that weed free plots produced 95.1 per cent as much fodder and 99.12 per cent as much grain as the cultivated ones. Call and Sewell (1917) concluded from their field experiments on cultivation in relation to soil moisture that cultivation other than for the control of weeds is of little value. Veihmeyer (1927) studied the loss of water through evaporation under a wide range of conditions and found that dust mulch did not produce significant conservation of soil moisture.

Bever (1958) indicated that the flow of water in soil is very slow at moisture contents below the field capacity and stated that the use of herbicides for weed control has eliminated the necessity for cultivation under many situations. Chougule and Khare (1961) studying the effect of interculture and weeding on the yield of rainfed cotton, observed that the yield of cotton in the weeded plot and weeded and intercultivated plot was significantly superior to interculture alone. Chougule and Khuspe (1962) observed no difference in yield of groundnut between hand weeded and intercultivated plots.

Verma and Bharodwaj (1963) reported superiority of hand weeding over hoeing in cotton. Burnside and Wicks (1964) studying the effects of cultivations, hand weeding and herbicidal control of weeds on dryland sorghum, concluded that on soil types where weeds were controlled by hand weeding or herbicides cultivations were neither advantageous nor necessary. Kramer (1965) reported spraying potato ridges with an effective herbicide mixture, obviates the need for post-emergence cultivation without adversely affecting the yield or starch content of the tuber.

VI. CULTURAL AND CHEMICAL METHODS OF WEED CONTROL IN RELATION TO CROP YIELD

Subba Rao and Agarwall (1966) from a trial with stem F-34 on gorra-paddy reported that rice yield under herbicide treatment was much higher than in hand weeding. Singh and Lorer (1966) from a two years trial on wheat concluded that on an average yields were higher with chemical method of weeding than with hand weeding. Mathur and Singh (1965) reported that weed control with simazine resulted in higher crop yields than that obtained on cultivated controls.

Chackravarthi (1961) and Mathur (1961) observed from weed control experiments on sorghum that a combination of 2,4-D application along with cultural controls resulted inthe highest net profits though weed control by either methods were satisfactory. Brasesco (1962) reported that weed control

with simazine or atrazine increased sorghum yields by 16 per cent over plots in which weeds were controlled by hoeing. Fodder yields of sorghum was also higher in the chemically controlled plots. Verma and Bharadwaj (1963) reviewing weed control experiments conducted at Bombay concluded that a combination of pre and post-emergence application of 2,4-D along with one hand weeding in between has given the highest yields and net profit.

Burnside and Wicks (1964) studying the effects of cultivations, hand weeding and herbicidal control on dryland sorghum found that treatments of atrazine and propazine increased grain yields above those of cultivated plots and atrazine resulted in yields equavalent to hand weeded plots. Weise and Burnside (1965) reported that pre-emergence application of atrazine or propazine to sorghum followed by one cultivation resulted in higher grain yields than those from untreated plots receiving four cultivations.

Phillips and Rose (1965) comparing the effects of pre-emergence application of propazine, post-emergence application of atrazine and mechanical cultivation on ten grain sorghum hybrids found that the herbicide treatments gave significantly higher yields than mechanical cultivations. George et al. (1967) investigating the effect of post-emergence application of atrazine on five varieties of grain sorghum found no significant difference in grain yield between herbicide treated and the cultivated control.

VII. RESIDUAL EFFECTS

a) Herbicide residue in plants: Arle (1962) from a weed control experiment on sorghum using atrazine and propazine applied to the soil before sowing at the rate of four pounds per acre, reported slight herbicidal residues in grain samples of sorghum. Colly and Harris (1966) studying the effect of atrazine with labelled chemicals applied to maize at the rate of two pounds per acre found no unaltered residue in maize.

Geigy (1966) reported that in United Kingdom, Switzerland and United States, spectrophotometric determinations made over several years on fruits from crops treated with simazine at the recommended dose of one to five pounds per acre applied for weed control showed no detectable residues of simazine. George et al. (1967) in an experiment with five varieties of grain sorghum treated with post-emergence application of atrazine at 2.7 kilogram per hectare found no significant difference in the protein content, soluble and total carbohydrates of grain samples between the treated and untreated group.

b) Effect of herbicide sprays on viability of sorghum seeds: Burnside and Wicks (1965) studying the effects of herbicides and cultivation on dryland sorghum reported that there was no significant difference in sorghum germination between weedy and hand weeded treatments. Among herbicides higher rates of CDAA plus TCBC significantly reduced sorghum germination below hand weeded and several herbicide treated

plots. George et al. (1967) studying the effects of post-emergence application of atrazine at 2.7 kilograms per hectare on grain sorghum found that the germination percentage or percentage of seed set did not differ between the treated and control group.

c) Effect of herbicide sprays on dormancy of weed seeds: High initial dormancy in many species of weeds have been reported by Harper (1960), Schonbeck (1965), Chabrolin (1965) and Chancellor (1965). Aberg (1956) reported that when certain weeds are sprayed with harmone weed killers the seeds produced are nondormant. Thurston (1960) stated that this should be investigated further both for its value in weed control and for the light it might throwm on the mechanism of dormancy.

d) Effect of herbicide residue in soil on succeeding crop: Minakova (1963) from laboratory and field experiments reported that 2,4-D was rapidly leached from soil. Ilin (1965) reported that in sterile soil the rate of decomposition of 2,4-D increased as the humus content increased.

Ivey and Andrews (1965) studying the leachability of herbicides in soil columns concluded that atrazine was readily leached in lighter soils than in heavy soils. Sikka and Davis (1966) studied the dissipation of atrazine from soil by corn, sorghum and johnson grass and concluded that in all cases atrazine persisted one month longer in the fallow plot.

It is suggested that in addition to direct uptake by crop, changes in microbial population associated with crops might have caused degradation. McCormic and Hiltbold (1966) studying the decomposition of atrazine reported that the decomposition of atrazine approximately doubled with each 10° rise of temperature upto 30° centigrade and paralleled organic matter decomposition.

Lozovatskaya (1963) found that cotton sown in summer after harvesting maize treated with simazine and atrazine at three kilograms per hectare suffered slight reductions in yield. Samiy (1964) observed that residue from atrazine applied to grain maize delayed the development of succeeding cereal crops. Lyubenov (1965) reported that atrazine applied at three kilograms per hectare in the previous year was toxic to wheat in dry year when pre-sowing tillage was only to a depth of six to eight centimetres.

Sarpe et al. (1964) from an experiment found that wheat and peas sown on plots previously treated with atrazine at three pounds per acre showed no injury while sunflower was severely affected. Peters (1966) in a long term experiment to study the tolerability of oats-lucerne mixture following maize after one, two or three years of using herbicide in conjunction with continuous maize observed no injury where atrazine treatment of maize was limited to two pounds per acre as pre-emergence every year. A rate of four pounds pre-sowing applied to maize injured oats and lucerne.

Kosovac (1965) found that application of atrazine to maize was not completely inactivated during the maize season but the amounts detectable by bioassay was not harmful to winter wheat.

Lamba and Verma (1962) studying the influence of high rates of different herbicides on succeeding wheat reported that application of dalapon, simazine and aminotrazole had not affected germination, height, ear length, grain yield per plant and 1000-grain weight of winter wheat sown eight to 10 weeks after treatment but grain yield and straw yield was increased by 47 and 37 per cent respectively over the control. Buka (1966) studied the residual effects of herbicide applied to maize by drilling wheat in the maize plots and found that atrazine, simazine and 2,4-D at 1.5 to three kilogram per hectare did not adversely affect growth. Nazlukina et al. (1966) observed similar results on the following years crop of carrot, beat, cabbage and tomatoes when the rate of application was 1.5 kilograms. Stroube (1967) reported similar observation on oats, wheat and soybean following atrazine treated corn at the rate of two pounds per acre.

VIII. ECONOMICS OF WEED CONTROL WITH HERBICIDES

Vachani et al. (1963) investigating the economics of weed control in rice found that MCPA treatment was a practicable alternative to mechanical means of weed control. Mani et al.

(1967) from a weed control trial on wheat using 2,4-D sodium salt and cultural methods concluded that the chemical method of weeding was cheaper than manual weeding with kurupi.

Dicker (1964) stated, in quoted examples returns on outley incurred for weed control measures ranged from 29 to 1000 per cent.

Mathur (1961) comparing the economics of different weed control methods adopted on sorghum at Sawaimadhopur farm reported a maximum net profit of rupees 109 per acre over control for post-emergence application of 2,4-D twice while the corresponding figure for local method of weeding was rupees 77 and for combination of local method of weeding with pre and post-emergence application of 2,4-D it was rupees 100.

Chackravarthi (1961) studying the economics of weed control on sorghum, reported a net profit of rupees 16.32 per acre for cultural method of weeding and rupees 6.87 for weeding with 2,4-D. Verma (1963) reported a maximum net profit of rupees 66.56 per acre for hoeing and weeding and rupees 49.41 for post-emergence application of 2,4-D by controlling weeds on rainfed sorghum.

Verma and Bharadwaj (1963) reviewing the weed control experiments of Bombay State on sorghum, reported profits from 2,4-D applications, but the maximum net profit was obtained from a combination of cultural and chemical methods of weeding.

MATERIALS AND METHODS

MATERIALS AND METHODS

The experiment was laid out to study the possibility of weed control in sorghum with selective herbicides and to compare the efficiency of herbicides with the conventional cultural methods. The effect of weed control methods on plant characters and the correlation between weed growth and crop yield was also tested. The effects of intercultivation on crop growth and yield were investigated and the economics of weed control by different methods worked out.

MATERIALS

1. Field: This experiment was laid out in Field No.8 of new area of the Central Farm, Agricultural College and Research Institute, Coimbatore. The study was carried out in the year 1967, during the South West Monsoon season from August to December. No herbicide or manurial trial was conducted in this field during the last five years and therefore, the residual effect may be considered to be nil.

2. Soil: The soil was a fairly fertile well drained medium black belonging to the Periasemkanpalayam silty clay loam. The mechanical and chemical analyses of the soil were conducted before laying out the trial and the soil had the following composition.

Mechanical analysis (air dry basis):

Coarse sand	...	17.093 per cent
Fine sand	...	19.635 "
Silt	...	29.020 "
Clay	...	31.820 "
Acid solubles	...	2.432 "

Chemical analysis (moisture free basis)

Moisture	...	5.180 per cent
Total nitrogen	...	0.078 "
Total phosphoric acid (P_2O_5)	...	0.092 "
Total potash (K_2O)	...	0.626 "
Lime (CaO)	...	3.090 "
Magnesia (MgO)	...	0.748 "
pH	...	8.00
EC	...	1.1 millimhos/Cm

3. Crop: The variety K-3 sorghum evolved at Koilpatti by hybridisation of the popular grain variety Co.1 with the fodder variety K-1 (irrungu cholam) was selected for the study. The crop duration is about 125 days and it yields fodder of good quality and hence is a fodder-cum-grain variety. The seeds gave an average of 84 per cent germination.

4. Manures: A uniform basal dressing of well rotten farm yard manure at the rate of 12.5 tonnes per hectare followed by 44.8 kilograms nitrogen in the form of ammonium sulphate and 22.4 kilograms phosphoric acid per hectare in the form of

super phosphate were applied and incorporated.

5. Weed control: Two cultural methods of weed control were compared with seven herbicidal methods.

A. Cultural

i) Hoeing and weeding twice with hand hoe: The most common method of weeding adopted in the locality is hand hoeing, a light digging with hand hoe which uproots and cuts the weeds. The uprooted weeds were collected and removed from the field. Thus, the soil gets a light intercultivation along with weeding.

ii) Hand pulling of weeds twice: All weeds in the plot were pulled out by hand and removed leaving the soil undisturbed and weed free. The treatment was included to study the effect of interculture on sorghum, under the existing soil and climatic conditions of the locality.

B. Herbicidal

Two new selective herbicides namely atrazine and ramrod were tried along with 2,4-D, the common selective herbicide.

i) Atrazine: The active ingredient is 2-chloro-4-ethylamino-6-isopropylamino-S-triazine. The herbicide was developed by J.R.Geigy S.A.Basle, Switzerland. Pure chemical is very little soluble in water, stable, non-flamable and has acute oral toxicity.

The herbicide is absorbed by the plants through the roots and leaves. The seedlings and older plants are also susceptible. It inhibits photosynthesis which results in the mortality of the plants. The chemical is metabolised by certain plants such as sorghum, maize, etc. and so it acts as a selective herbicide when used in such crops. Atrazine is suitable for pre-emergence and post-emergence applications.

A formulation containing 50 per cent active ingredient in the form of a wettable powder supplied by Messrs. Tata-Pison and Company, Bombay was used.

ii) Ramrod-65: The active ingredient is 2-chloro-N-isopropylacetanilide. It is a product recently developed by Monsanto Agricultural Division, St.Louis, Missouri, U.S.A. The chemical is intended as a pre-emergence herbicide which controls many grasses and broad leaved weeds, effective on a variety of soils and persists up to eight weeks. It is reported to be extremely selective for pre-emergence weed control in maize.

The formulation used was a wettable powder containing 65 per cent active ingredient, supplied by Messrs. Monsanto Chemicals of India, Madras.

iii) 2,4-Dichlorophenoxyacetic acid: This synthetic growth regulator prepared by Pokorny in 1941 is being widely used as a selective herbicide in cereal crops. It is readily absorbed both through the root and shoot. Dicotyledonus

plants and seedling grasses are susceptible to its action. In susceptible plants 2,4-D accumulates in toxic levels in regions of active metabolism and induce cell division, enlargement, growth aberrations, disorganisation of vascular tissues, abnormal metabolism and in extreme cases death. The herbicide is used for pre-emergence and post-emergence applications.

Bladex-A, a most selective water soluble formulation of 2,4-D containing 80 per cent acid equivalent sodium salt supplied by Messrs. Burma-Shell and Company, Madras was used in this trial.

METHODS

1. Experimental design and lay out: Since the study was for the comparison of 10 treatments, the randomised block design was found to be most suitable (Panse and Sukhatme, 1957). The plan of the lay out adopted is given in Figure No.1 and the details are furnished below:

Design	...	Randomised block
Number of treatments	...	Ten
Number of replications	...	Three
Size of plot (Gross)	...	9.144 metres x 8.839 metres
Size of plot (Net)	...	7.344 metres x 8.239 metres

2. Fixing of doses and time of application: Since the herbicides chosen were to be evaluated for selective action in sorghum the more frequently recommended dosages and times of application were adopted.

A. Atrazine: A review of previous work with atrazine on sorghum shows that the dose ranges from half to two kilograms active ingredient per hectare for pre-emergence application. A low dosage was found to be suitable for light soils and a higher dosage optimum for heavy soils. In this trial the soil being medium type a standard dosage of 1.12 kilogram-active ingredient per hectare was fixed. The application was made a day after sowing after a pre-soaking irrigation.

For treatments receiving pre and post-emergence applications, the post-emergence spray was given 48 days after sowing at the rate of 1.12 kilogram of active ingredient per hectare.

Most of the early workers have reported effectiveness of early post-emergence application of atrazine when the crop is at the five to six leaf stage. In treatments receiving a single post-emergence application a slightly higher dose of 1.68 kilogram-active ingredient per hectare was fixed and applied 18 days after sowing at the five to six leaf stage of sorghum. The crop was 15 to 20 centimeters tall.

B. Ramrod: The dosage of 4.4 kilogram-active ingredient per hectare of ramrod as pre-emergence as recommended by

Messrs. Monsanto Company was adopted. A similar dose was tried by Burnside (1966) for sorghum. The spray was given a day after sowing to the wet soil.

C. 2,4-Dichlorophenoxyacetic acid: Rahudkar (1959) could completely control annual grasses and broad leaf weeds in sorghum by pre-emergence application of 0.2 per cent sodium salt of 2,4-D. In the Co-ordinated Weed Control Scheme, Nagpur (1955-60) a combination treatment of one pre-emergence at 1.5 pounds and a post-emergence at one pound acid equivalent per acre along with cultural methods proved to be effective in controlling weeds in sorghum fields. Verma (1963) recorded better yields from post-emergence application at two pounds acid equivalent per acre applied four weeks after sowing. Verma and Bharadwaj (1963) recommended post-emergence application of 2,4-D on seven weeks old jower following a cultural operation. Klingman (1965) reported, most varieties of grain sorghum at five to eight leaf stage or when 15 to 20 centimeters tall to tolerate 2,4-D ester or amine salts.

Based on the above observations a dose of 1.68 kilogram acid equivalent per hectare for pre-emergence a day after sowing and 2.24 kilogram acid equivalent per hectare for post-emergence at the five leaf stage (third week) was fixed. For the combination treatment of pre and post-emergence, the post-emergence application at the same rate was given 46 days after sowing (seventh week).

3. Treatments: The details of treatments are as follows:

T_0 ... Control

T_1 ... Hoeing and weeding with hand hoe twice, first 18 days after sowing and second, 48 days after sowing.

T_2 ... Hand pulling of all the weeds twice, first 18 days after sowing and second 48 days after sowing.

T_3 ... 2,4-D pre-emergence at the rate of 1.68 kg acid equivalent per hectare a day after sowing.

T_4 ... 2,4-D pre-emergence as in T_3 followed by 2,4-D post-emergence at the rate of 2.24 kg acid equivalent per hectare, 48 days after sowing.

T_5 ... 2,4-D post-emergence, 18 days after sowing at the rate of 2.24 kg acid equivalent per hectare.

T_6 ... Ramrod pre-emergence, 4.4 kg active ingredient per hectare, a day after sowing.

T_7 ... Atrazine pre-emergence, at the rate of 1.12 kg active ingredient per hectare, a day after sowing.

T_8 ... Atrazine pre-emergence as in T_7 followed by atrazine post-emergence at the rate of 1.12 kg active ingredient per hectare, 48 days after sowing.

T_9 ... Atrazine post-emergence at the rate of 1.68 kg active ingredient per hectare, 18 days after sowing.

4. Rate of dilution and method of application: The formulations were dissolved in irrigation water and sprayed. The rate of dilution was 250 litres of water per hectare for ramrod and 500 litres of water per hectare for atrazine and 2,4-D. The solution was applied uniformly as a blanket spray in the respective plots using a hand operated Pneumatic Knapsack sprayer, in the early hours to avoid spray drift.

The untreated plots were given a spray with irrigation water for the sake of uniformity on all the occasions of herbicide applications.

5. Experimental procedure: The preparatory cultivation started during the first week of July, 1967. The field was ploughed twice and the Carbridge roller was passed to break the clods. Manures and fertilisers as per the schedule were applied and incorporated before the final ploughing. Beds and channels were formed with a bund former and rectified with human labour.

The seeds were treated with sulphur at the rate of two grams per kilogram and was sown on 10-8-1967 by dibbling four seeds per hole. The seeds were dibbled in line with a spacing of 45 centimeters between lines and 15 centimeters between points. Border rows were sown on all sides with the same variety. The seedlings were later thinned to one plant per hole. The first irrigation was given soon after sowing and the life irrigation was given four days after. Subsequently, the crop was irrigated eight times. Prophylactic sprayings with metasystox, endrin and copper fungicides were given to protect the crop from pests and diseases.

The crop was harvested on 13-12-1967. Two rows of plants on all sides of the plot were harvested and removed first as border. The net plot was separately harvested, the earheads were collected, dried, threshed, cleaned and the grain yield in each plot recorded.

6. Observations made:

A. Plant characters

i) Plant height
ii) Number of leaves
iii) Leaf area from length and breadth
iv) Thickness of peduncle
v) Length of earhead
vi) Breadth of earhead
vii) Weight of earhead
viii) Weight of grain per ear
ix) 1000-grain weight
x) Yield of straw per plant

B. Field observations

i) Crop emergence
ii) Plant establishment
iii) Crop injury
iv) Grain yield per plot
v) Straw yield per plot

C. Weed study

i) Weed species
ii) Weed population
iii) Dry weight of weeds
iv) Weed control (based on weight of weeds)
v) Relationship of weed growth with crop yield

D. Economics of weed control

E. Residual effects

i) Herbicide residue in crop

ii) Fertility of sorghum seed

iii) Fertility of weed seed

iv) Effect of herbicide application on subsequent crop

Observations were made and data collected on the growth characters and yield attributes of the crop to estimate the effect of various treatments.

The relation of weed growth and crop yield was studied by estimating the population and dry weight of weeds and working out their correlations with yield. The efficiency of various weed control methods adopted was assessed from the weed study.

Residual effect of herbicides on the crop and weed was investigated.

A. Plant characters

Ten sorghum plants were selected at random in the net plot area and numbered for studying the plant characters. Measurements of morphological characters were recorded following the procedure laid down by Ayyangar (1942).

i) Plant height: The height of the plant was measured at full flowering stage from the base of the plant to the tip of the panicle in centimeters with a metre scale.

ii) Number of leaves: The total number of leaves per plant as indicated by the number of distinguishable nodes above ground level were counted after completion of flowering.

iii) Leaf area: The fourth leaf from the top has been proved to be a fair sample after detailed investigations by Ayyangar (1942). The length and maximum breadth of the fourth leaf from the top was measured in centimeters. The leaf area was estimated by multiplying the product of length and breadth with a factor 0.747 as formulated by Stickler et al. (1961).

iv) Thickness of peduncle: The thickness of the peduncle was measured at a standard distance of five centimeters below the earhead base with vernier calipers.

v) Length of earhead: The length of the earhead was measured from the basal whorl of branches to the tip of the head with a metre scale.

vi) Breadth of earhead: The breadth of the earhead was measured by placing it across a metre scale and bringing together two blocks of wood with rectangular faces so as to touch the earhead on either side without pressing it. The distance between the inner faces was read from the scale which directly gives the maximum breadth of the ear.

vii) Weight of the earhead: The weight of the earhead along with standard five centimeters stalk, with which it was cut, was recorded in grams after drying.

viii) Weight of grain per earhead: The heads were threshed separately by hand and the weight of grain recorded for all ten earheads.

ix) 1000-grain weight: Hundred grains each at random were collected from all the ten earheads, air dried and the weight of 1000 grains recorded in grams.

x) Yield of straw per plant: The straw of the selected plants were air dried and their weights recorded in grams.

B. Field observations

i) Crop emergence: A germination study was conducted to estimate the effect of pre-emergence sprays on the germination of seeds. The number of germinated points in alternate rows were counted 10 days after sowing and the germination expressed as a percentage of the total points sown per row.

Similar method was adopted by Sharadwaj and Verma (1961) to estimate the effect of pre-emergence sprays on germination of wheat.

ii) Plant establishment: The mean number of sorghum plants established per metre length of the row at full flowering in each plot was estimated by counting the number of plants per

metre length of the row at randomly selected rows. The study was undertaken to estimate the effect of herbicides and weed growth on plant establishment.

This method was adopted by Saber et al. (1965) in grain sorghum and Jeater and Mc ilvenny (1965) in cereals.

iii) Crop injury: The degree of susceptibility of sorghum to herbicide application was assessed visually adopting the ratings given below. Observations were made up to two weeks after the post-emergence application.

Such assessment of crop injury was made by Burnside and Robinson (1967) on grain sorghum and Bayer (1967) on maize.

Effect of herbicide	Rating
No visible effect	0
Slight scorching on leaves	1
Leaves turning yellow	2
Moderate scorching of leaves	3
Moderate scorching of leaves and ster	4
Severe scorching on leaves and stem	5
Death of young shoots	6
25 per cent kill	7
50 per cent kill	8
75 per cent kill	9
100 per cent kill	10

C. Weed study: To estimate the effect of various weed control methods, weed assessment in each plot was taken up at two stages, first at 45 days after sowing corresponding to the shade out stage and second at 75 days after sowing at full flowering of the crop. The study included weed species, population count, density of growth, extent of control and relation of weed growth on crop yield.

The estimation was done by throwing a wooden quadrat 0.9144 metre square (one yard square) at random in each plot and collecting the weeds enclosed by clipping them close to the ground. This method was adopted by Bharadwaj and Verma (1961), Verma (1963), Burnside and Wicks (1965) and Thakur et al. (1967).

i) Weed species: The weeds in the control plot was classified into different species and the number in each species was recorded separately. In the treatment plots the weeds were grouped into grasses, sedges and dicots and the number of each group recorded.

ii) Weed population: The total number of weeds per quadrat was counted and recorded.

iii) Dry weight of weeds: All the clipped weeds were air dried and the total dry matter per quadrat was determined by recording the weight in grams.

iv) Weed control: Weed control in each plot was estimated as the percentage reduction of weed weight over control.

v) Relationship of weed growth with crop yield: The relationship between weed growth and crop yield was estimated by means of the simple correlation coefficient of grain and straw yield with the weed growth (weight) on the other. The linear regression of grain and straw yields on weed weight was also worked out and a linear prediction equation was fitted for estimating the grain and straw yields for given values of weed growth.

D. Economics of weed control: Economics of the different methods of weed control was worked out in detail, taking into account the cost of the chemicals, cost of cultural methods and value of extra yield of grain and straw over the control.

E. Residual effects

i) Herbicide residue in crop: Composite samples of leaf and grain were collected from the control and atrazine treated plots at the time of crop harvest. The samples were analysed by the spectrophotometric method (Procedure given by Gunter Zwig, 1964). Facilities for estimation of ramrod and 2,4-D were not available and so it was not undertaken.

ii) Fertility of sorghum seed: The earheads collected at random from the differently treated plots at the time of harvest was hand threshed, cleaned, dried and stored. The

germination of the seed was tested after one month in petridish under standard conditions. Germination counts were recorded on the seventh day and the data on germination were analysed statistically. The seeds from the herbicides treated plots were compared with that from the hand weeded plot as control and hence the total number of treatments in this case was only eight.

iii) Fertility of weed seeds: Seeds of the predominent weed viz., Trianthema portulacastrum which survived in the herbicide treated plots and in the hand weeded control were collected and the germination studied by conducting germination tests in petridishes on filter paper medium. The germination was tested three months after collection since the seeds were dormant at the early stages. The germination percentages were recorded.

iv) Effect of herbicide application on subsequent crop: After harvest of the sorghum crop representative soil samples were collected from each of the herbicide treated and control plots from zero to ten centimeters depth in pots of standard size. After one month cotton and ragi seeds were sown in the pots and after emergence seedlings were thinned to three each per pot and the subsequent growth was observed. Cotton seedlings were observed for 20 days after emergence and ragi up to flowering stage. The crop injury was assessed by rating method as indicated elsewhere.

Schweizer and Holstun (1966) estimated the residual effects of chlorthal methyl, diuron, norea, prometryne and trifluralin by sowing oats, cotton and soybean on soils collected from treated fields.

EXPERIMENTAL RESULTS

Table 1. Comparison of treatment means (Plant height)

Treatments	Mean plant height in cm	SE_D	C.D. (P=0.05)
T_0 - Control	168.36		
T_1 - Hoeing and weeding	222.76		
T_2 - Hand weeding	212.30		
T_3 - 2,4-D pre-emergence	205.46		
T_4 - 2,4-D pre+post-emergence	176.56	10.53	22.12
T_5 - 2,4-D post-emergence	183.73		
T_6 - Romrod pre-emergence	187.86		
T_7 - Atrazine pre-emergence	252.56		
T_8 - Atrazine pre+post-emergence	243.93		
T_9 - Atrazine post-emergence	243.43		

Conclusion: $\overline{T_7\ T_8\ T_9}\ \underline{T_1\ T_2\ T_3}\ \underline{T_6\ T_5\ T_4\ T_0}$

Table 4. Comparison of treatment means (Number of leaves)

Treatments	Mean number of leaves	SE_D	C.D. (P=0.05)
T_0 - Control	8.266		
T_1 - Hoeing and weeding	9.460		
T_2 - Hand weeding	9.033		
T_3 - 2,4-D pre-emergence	9.066		
T_4 - 2,4-D pre+post-emergence	8.366	0.351	0.7374
T_5 - 2,4-D post-emergence	8.566		
T_6 - Romrod pre-emergence	9.033		
T_7 - Atrazine pre-emergence	9.800		
T_8 - Atrazine pre+post-emergence	9.400		
T_9 - Atrazine post-emergence	9.460		

Conclusion: $\overline{T_7\ T_9\ T_1\ T_8\ T_3}\ \underline{T_2\ T_6\ T_5\ T_4\ T_0}$

EXPERIMENTAL RESULTS

An investigation was undertaken to study the comparative efficiency of various cultural and herbicidal methods of weed control and the results are presented in the following pages.

In general, the various treatments produced significant effects on plant height, leaf number and area, length, breadth and weight of earhead, grain and straw yield, crop stand and on weed growth. But the 1000-grain weight and crop emergence was not affected.

A. Plant characters

i) Plant height: Data on plant height measurements at full flowering were analysed and the analysis of variance presented (Appendix I). The different treatment effects were found significant.

A comparison of the treatment means reveal that the three treatments of atrazine, the two cultural methods and pre-emergence application of 2,4-D were superior to control (Table 1). The pre-emergence application of atrazine was superior to the cultural methods. Ramrod and post-emergence application of 2,4-D were not better than the control.

Comparing the times of applications within herbicides, pre-emergence application of 2,4-D was superior to post-emergence and a combination of pre and post-emergence

application whereas in the case of atrazine such differences between times of applications were not observed.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 2. Comparison of control with rest

Treatments	Mean plant height in cm	SE_D	C.D. (P=0.05)
Control	168.36	7.84	16.47
Rest	214.29		

Conclusion: Rest Control

Difference between control and rest of the treatments was significant at P=0.01 indicating that the weed control methods adopted increased sorghum height.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

The different cultural and chemical methods adopted did not affect the plant height significantly.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1 Vs. T_2)

No significant difference was found in plant height between these two cultural methods of weed control.

4. Time of application of herbicide (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

No significant difference was found between the different times of application of herbicides viz., pre-emergence, pre and post-emergence and post-emergence of the three herbicides taken together.

5. Between herbicides (T_3, T_4 and T_5 Vs T_6, Vs. T_7, T_8 and T_9)

Table 3. Comparison between herbicides

Herbicides	Mean plant height in cm	SE_D	C.D.(P=0.05)
Atrazine	246.64	6.07	12.753
2,4-D	188.58	8.59	18.047
Ramrod	187.86		

Conclusion: Atrazine 2,4-D Ramrod

Herbicides 2,4-D, ramrod and atrazine produced highly significant difference in plant height, atrazine was superior to both 2,4-D and ramrod. The difference between 2,4-D and ramrod was not significant.

6. Interaction of herbicides with time of application

The interaction effects of herbicides 2,4-D and atrazine with times of application were not significant.

ii) Number of leaves: The data on number of leaves per plant at flowering were analysed and the analysis of variance

presented (Appendix II). The different treatment effects were found to be significant at P=0.01.

All the treatments of atrazine, the cultural methods, pre-emergence application of 2,4-D and roguing have significantly increased leaf number than the unweeded control (Table 4). Pre-emergence application of atrazine was superior to hand weeding. Post-emergence applications of 2,4-D were not superior to control. The difference between times of application was not significant either in the case of 2,4-D or atrazine.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 5. Comparison of control with rest

Treatments	Mean number of leaves	SE_D	C.D.(P=0.05)
Control	8.27	0.262	0.5506
Rest	9.13		

Conclusion: Rest Control

The difference between control and rest of the treatments was significant at P=0.01 showing that the different methods of weed control adopted increased the leaf production of sorghum.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

The different cultural and chemical methods adopted did not produce significant difference in the number of leaves showing that weed control by chemical methods was as good as the conventional cultural methods.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1 Vs. T_2)

No significant difference was found in the number of leaves on sorghum, between these two cultural methods of weed control.

4. Time of application of herbicide (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

The comparison of different times of application of herbicides viz., pre-emergence, pre and post-emergence and post-emergence did not reveal any significant difference in leaf number.

5. Between herbicides (T_3, T_4 and T_5 Vs. T_6 Vs. T_7, T_8 and T_9)

Table 6. Comparison of herbicides

Herbicides	Mean number of leaves per plant	SE_D	C.D.(P=0.05)
Ramrod	9.033	0.287	0.6029
2,4-D	8.660	0.202	0.4240
Atrazine	9.550		

Conclusion: Atrazine Ramrod 2,4-D

Table 7. Comparison of treatment means (Leaf area)

Treatments	Mean leaf area in Sq.cm.	SE_D	C.D. (P=0.05)
T_0 - Control	172.41		
T_1 - Hoeing and weeding	315.23		
T_2 - Hand pulling	286.04		
T_3 - 2,4-D pre-emergence	232.03		
T_4 - 2,4-D pre+post-emergence	182.95	16.02	33.65
T_5 - 2,4-D post-emergence	217.48		
T_6 - Ramrod pre-emergence	230.74		
T_7 - Atrazine pre-emergence	354.35		
T_8 - Atrazine pre+Post-emergence	364.06		
T_9 - Atrazine post-emergence	352.66		

Conclusion: $\overline{T_8\ T_7\ T_9}\ \underline{T_1\ T_2}\ \overline{T_3\ T_6\ T_5}\ \underline{T_4\ T_0}$

Table 11. Comparison of treatment means (Thickness of peduncle)

Treatments	Mean thickness in cm	SE_D	C.D. (P=0.05)
T_0 - Control	0.554		
T_1 - Hoeing and weeding	0.750		
T_2 - Hand weeding	0.745		
T_3 - 2,4-D pre-emergence	0.665		
T_4 - 2,4-D pre+post-emergence	0.647	0.0316	0.0664
T_5 - 2,4-D post-emergence	0.626		
T_6 - Ramrod pre-emergence	0.639		
T_7 - Atrazine pre-emergence	0.796		
T_8 - Atrazine pre+post-emergence	0.792		
T_9 - Atrazine post-emergence	0.776		

Conclusion: $\overline{T_7\ T_8\ T_9\ T_1\ T_2}\ \overline{T_3\ T_4\ T_6\ T_5}\ T_0$

A comparison of the different herbicides 2,4-D, ramrod and atrazine shows that they exert highly significant effects on the number of leaves. Atrazine though on par with ramrod was superior to 2,4-D.

6. Interaction of herbicides with times of application

The interaction effects of herbicides 2,4-D and atrazine with times of application were not significant.

iii) Leaf area: The data on leaf area of sorghum plants measured at full flowering were analysed and the analysis of variance presented (Appendix III). The different treatment effects were found significant at P=0.01.

A comparison of treatment means reveal that all the methods of application of atrazine was significantly superior to the other treatments in increasing leaf area (Table 7). The difference between times of application was not significant in atrazine whereas in 2,4-D, pre-emergence and post-emergence application was superior to a combination of the two.

The cultural methods were inferior to atrazine but were superior to treatments of 2,4-D, ramrod and control. Pre-emergence application of 2,4-D and ramrod and post-emergence application of 2,4-D were better than control.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 8. Comparison of control with rest

Treatments	Mean leaf area in Sq.cm	SE_D	C.D.(P=0.05)
Control	172.41	12.13	25.4851
Rest	281.74		

Conclusion: Rest Control

The difference between control and rest of the treatments was significant at P=0.01 indicating that the different methods of weed control adopted lead to an increase in the leaf area.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

Table 9. Comparison of cultural with chemical methods

Treatments	Mean leaf area in Sq.cm	SE_D	C.D.(P=0.05)
Cultural	300.63	9.12	19.161
Herbicidal	276.32		

Conclusion: Cultural Herbicidal

There was significant difference between the cultural and chemical methods of weed control. The leaf area in cultural methods was more than that in the herbicidal treatments.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1 Vs. T_2)

A comparison between hoeing and weeding and hand pulling of weeds did not record significant difference in leaf area.

4. Time of application of herbicides (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

The different times of application of herbicides viz., pre-emergence, pre-emergence and post-emergence and post-emergence produce no significant difference between themselves in leaf area.

5. Between herbicides (T_3, T_4 and T_5 Vs. T_6 Vs. T_7, T_8 and T_9)

Table 10. Comparison between herbicides

Herbicides	Mean leaf area in Sq.cm	SE_D	C.D.(P=0.05)
Ramrod	230.74	13.22	27.775
2,4-D	210.82	9.25	19.430
Atrazine	357.60		

Conclusion: Atrazine Ramrod 2,4-D

The different herbicides 2,4-D, ramrod and atrazine produce highly significant difference in leaf area of the plant. Atrazine was superior to both 2,4-D and ramrod in increasing the leaf area and 2,4-D and ramrod were on par.

6. Interaction of herbicides with times of application

The interaction effects of herbicides, 2,4-D and atrazine with the times of application were significant.

iv) Thickness of peduncle

Data on thickness of the peduncle measured at the time of harvest were analysed and the analysis of variance presented (Appendix IV). The treatment differences were found to be significant at P = 0.01.

All the treatments with atrazine and the two cultural methods were on par and was significantly superior to the rest of the treatments (Table 11). Herbicide treatments of 2,4-D and ramrod were on par and was superior to control. The differences between the times of application of herbicides were not significant either in atrazine or 2,4-D.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 12. Comparison of control with rest

Treatments	Mean thickness in cm	SE_D	C.D. (P=0.05)
Control	0.554	0.0236	0.0495
Rest	0.715		

Conclusion: Rest Control

The difference between the control and rest of the treatments was significant at $P = 0.01$ indicating that the different methods of weed control adopted lead to an increase in the thickness of peduncle.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

Table 13. Comparison of cultural with chemical methods

Treatments	Mean thickness in cm	SE_D	C.D.(P=0.05)
Cultural	0.747	0.018	0.0378
Chemical	0.706		

Conclusion: Cultural Chemical

The cultural and chemical methods differed significantly the cultural methods being superior to chemical methods in increasing the thickness of peduncle.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1 Vs. T_2)

No significant difference was found to exist in the thickness of peduncle between these two cultural methods of weed control indicate that both the methods were equally effective in increasing the thickness of peduncle.

4. Time of application of herbicides (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

A comparison of the different times of application of herbicides viz., pre-emergence, pre and post-emergence and

post-emergence showed no significant difference. The results indicated that all the times of application tried were equally effective.

5. Between herbicides (T_3, T_4 and T_5 Vs. T_6 Vs. T_7, T_8 and T_9)

Table 14. Comparison between herbicides

Herbicides	Mean thickness in cm	SE_D	C.D.(P=0.05)
Ramrod	0.639		
		0.0259	0.0544
2,4-D	0.646		
		0.0183	0.0384
Atrazine	0.768		

Conclusion: Atrazine 2,4-D Ramrod

The different herbicides, 2,4-D, ramrod and atrazine produce highly significant differences in the thickness of the peduncle. Atrazine was superior to both 2,4-D and ramrod in increasing the thickness, 2,4-D and ramrod being equal in their effect.

6. Interaction of herbicides with times of application

The interaction effects of 2,4-D and atrazine with times of application were not significant.

v) Length of earhead

Data on length of ripe ears were analysed and the analysis of variance presented (Appendix V). The different treatment effects were found significant.

Table 15. Comparison of treatment means (Ear length)

Treatments	Ear length in cm.	SE_D	C.D. (P=0.05)
T_0 - Control	18.276		
T_1 - Hoeing and weeding	20.990		
T_2 - Hand weeding	21.236		
T_3 - 2,4-D pre-emergence	19.110		
T_4 - 2,4-D pre+post-emergence	19.366	1.092	2.294
T_5 - 2,4-D post-emergence	19.393		
T_6 - Ramrod pre-emergence	20.370		
T_7 - Atrazine pre-emergence	22.106		
T_8 - Atrazine pre+post-emergence	22.190		
T_9 - Atrazine post-emergence	21.696		

Conclusion: $\underline{T_8\ T_7\ T_9\ T_2\ T_1}\ \overline{T_6\ T_5\ T_4\ T_3\ T_0}$

Table 16. Comparison of treatment means (Breadth of ear)

Treatments	Mean breadth in cm.	SE_D	C.D. (P=0.05)
T_0 - Control	2.923		
T_1 - Hoeing and weeding	4.230		
T_2 - Hand weeding	4.010		
T_3 - 2,4-D pre-emergence	4.080		
T_4 - 2,4-D pre+post emergence	3.226	0.3456	0.7261
T_5 - 2,4-D post-emergence	3.293		
T_6 - Ramrod pre-emergence	3.420		
T_7 - Atrazine pre-emergence	4.553		
T_8 - Atrazine pre+post-emergence	4.600		
T_9 - Atrazine post-emergence	4.786		

Conclusion: $\overline{T_9\ T_8\ T_7\ T_1\ T_3}\ \underline{T_2\ T_6\ T_5\ T_4\ T_0}$

The comparison of treatment means revealed that the different applications of atrazine and the two cultural methods were on par, but superior to 2,4-D treatments and control (Table 15). 2,4-D and ramrod were not significantly superior to unweeded control. The difference between the times of application was not significant either in atrazine or in 2,4-D.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 16. Comparison of control Vs. rest

Treatments	Ear length in cm	$SE_{\bar{d}}$	C.D.(P=0.05)
Control	18.276	0.814	1.710
Rest	20.710		

Conclusion: Rest Control

There was highly significant difference between control and rest of the treatments indicating that the different methods of weed control lead to an increase in the length of ear.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

The cultural and chemical methods did not vary the ear length significantly.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1 Vs. T_2)

The comparison revealed no significant difference in ear length between the two cultural methods of weed control.

The result thus indicated that both the methods were equally effective.

4. Time of application of herbicides (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

The different times of application viz., pre-emergence, pre and post-emergence and post-emergence did not produce any difference in ear length when all the herbicides were taken together.

5. Between herbicides (T_3, T_4 and T_5 Vs. T_6 Vs. T_7, T_8 and T_9)

Table 17. Comparison between herbicides

Herbicides	Mean ear length in cm	SE_D	C.D.(P=0.05)
Ramrod	20.37	0.892	1.870
2,4-D	19.29	0.630	1.323
Atrazine	21.99		

Conclusion: Atrazine Ramrod 2,4-D

The three herbicides 2,4-D, ramrod and atrazine produced highly significant difference in the length of ear. Atrazine was superior to 2,4-D but on par with ramrod.

6. Interaction of herbicides with times of application

The interaction effects of herbicides, 2,4-D and atrazine with times of application were not significant.

vi) Breadth of earhead

Data on the breadth of earhead were analysed and the analysis of variance presented (Appendix VI). The different treatment effects were found to be significant at P = 0.01.

A comparison of the treatment means revealed that post-emergence application of atrazine was superior to hand weeding, ramrod, post-emergence applications of 2,4-D and control (Table 18). Applications of atrazine, pre-emergence application of 2,4-D and hoeing and weeding were on par and was superior to rest of the herbicide applications and control. Pre-emergence application of 2,4-D was superior to post-emergence and combination of pre and post-emergence application of 2,4-D. Ramrod and post-emergence applications of 2,4-D was not superior to control.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 19. Comparison of control with rest

Treatments	Mean breadth of ear in cm	SE_D	C.D. (P=0.05)
Control	2.923	0.257	0.5399
Rest	4.022		

Conclusion: Rest Control

There was highly significant difference between control and rest of the treatments indicating that the different methods of weed control increased the breadth of the ear.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

The different cultural and chemical methods adopted did not produce significant difference in the breadth of the earhead.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1 Vs. T_2)

The comparison revealed no significant difference in the breadth of the ear between these two cultural methods of weed control.

4. Time of application of herbicide (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

The different times of application viz., pre-emergence, pre and post-emergence and post-emergence did not produce any significant difference on the breadth of the ear.

5. Between herbicides (T_3, T_4 and T_5 Vs. T_6 Vs. T_7, T_8 and T_9)

Table 20. Comparison of herbicides

Herbicides	Mean breadth of ear in cm	SE_D	C.D. (P=0.05)
Ramrod	3.420	0.282	0.5924
2,4-D	3.533	0.199	0.4012
Atrazine	4.646		

Conclusion: Atrazine 2,4-D Ramrod

Table 21. Comparison of treatment means (Weight of ear)

Treatments	Weight of ear in gm.	SE_D	C.D. (P=0.05)
T_0 - Control	19.733		
T_1 - Hoeing and weeding	52.266		
T_2 - Hand weeding	53.666		
T_3 - 2,4-D pre-emergence	38.500		
T_4 - 2,4-D pre+post-emergence	28.233	5.470	11.4924
T_5 - 2,4-D post-emergence	32.600		
T_6 - Ramrod pre-emergence	29.733		
T_7 - Atrazine pre-emergence	60.566		
T_8 - Atrazine pre+post-emergence	60.060		
T_9 - Atrazine post-emergence	60.000		

Conclusion: $\overline{T_7\ T_8\ T_9\ T_2\ T_1}\ \overline{T_3\ T_5\ T_6\ T_4}\ T_0$

Table 25. Comparison of treatment means (Weight of grain per ear)

Treatments	Weight of grain per ear in gm	SE_D	C.D. (P=0.05)
T_0 - Control	18.50		
T_1 - Hoeing and weeding	48.40		
T_2 - Hand weeding	50.50		
T_3 - 2,4-D pre-emergence	35.80		
T_4 - 2,4-D pre+post-emergence	26.10	5.135	10.788
T_5 - 2,4-D post-emergence	28.10		
T_6 - Ramrod pre-emergence	27.60		
T_7 - Atrazine pre-emergence	55.50		
T_8 - Atrazine pre+post-emergence	56.30		
T_9 - Atrazine post-emergence	56.00		

Conclusion: $\underline{T_8\ T_9\ T_7\ T_2\ T_1}\ \underline{T_3\ T_5\ T_6\ T_4}\ T_0$

Herbicides 2,4-D, ramrod and atrazine produced highly significant difference in the breadth of ear. Atrazine was superior to both 2,4-D and ramrod in increasing the breadth of the ear. The difference between 2,4-D and ramrod was not significant.

6. Interaction of herbicides with times of application

The interaction effects of 2,4-D and atrazine with times of application were not significant.

vii) Weight of earhead

Data on the weight of earhead were analysed and the analysis of variance presented (Appendix VII). The different treatment effects were found to be significant at P = 0.01.

The different treatments of atrazine and the cultural methods were on par and was significantly superior to rest of the treatments (Table 21). The pre-emergence application and post-emergence application of 2,4-D though inferior to the above treatments was significantly better than control.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 22. Comparison of control with rest

Treatments	Mean weight of ear in gm	SE_D	C.D.(P=0.05)
Control	19.733	4.077	8.565
Rest	46.181		

Conclusion: Rest Control

There was highly significant difference between control and rest of the treatments, indicating that the different methods of weed control adopted increased the weight of the earhead.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

Table 23. Comparison of cultural with chemical

Treatments	Mean weight of ear in gm	SE_D	C.D.(P=0.05)
Cultural	52.906	3.101	6.5152
Chemical	44.240		

Conclusion: Cultural Chemical

The cultural methods and chemical methods significantly vary the weight of the earhead. The cultural methods were superior to chemical methods.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1Vs.T_2)

No significant difference in earhead weight was found between these two cultural methods. Result indicated that both the methods were equally effective in increasing ear weight.

4. Time of application of herbicide (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

The different times of application of herbicides viz., pre-emergence, pre and post-emergence and post-emergence did not differ significantly from each other.

5. Between herbicides (T_3, T_4 and T_5 Vs. T_6 Vs. T_7, T_8 and T_9)

Table 24. Comparison of herbicides

Herbicides	Mean weight of ear in gm	SE_D	C.D. (P=0.05)
Ramrod	29.733	4.466	9.383
2,4-D	33.111	3.158	6.634
Atrazine	60.211		

Conclusion: Atrazine 2,4-D Ramrod

The herbicides, 2,4-D, ramrod and atrazine produce highly significant difference in the weight of the earhead. Atrazine was superior to both 2,4-D and ramrod whereas 2,4-D and ramrod behaved alike.

6. Interaction of herbicides with times of application

The interaction effects of herbicides 2,4-D and atrazine with times of application were not significant.

viii) Weight of grain per ear

The data on the weight of the grain per ear were analysed statistically and the analysis of variance presented (Appendix VIII). The different treatment effects were found to be significant at P = 0.01.

All the treatments of atrazine and the two cultural methods were on par and was superior to rest of the treatments (Table 25). Pre-emergence application of 2,4-D though inferior to cultural

and atrazine treatments was better than control. Hamrod and the post-emergence treatments of 2,4-D were not superior to control.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 26. Comparison of control with rest

Treatments	Mean weight of grain per ear in gm.	SEd	C.D. (P=0.05)
Control	18.5	3.62	8.025
Rest	42.7		

Conclusion: Rest Control

The difference between control and rest of the treatments was significant at P = 0.01 indicating that the different methods of weed control adopted increased the weight of grain per ear.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

Table 27. Comparison of cultural with chemical methods

Treatment	Mean weight of grain per ear in gm.	SEd	C.D. (P=0.05)
Cultural	49.45	2.91	6.11
Chemical	40.80		

Conclusion: Cultural Chemical

Comparison of the cultural methods with the chemical methods showed a significant difference in the weight of the grain per ear at P = 0.01. The cultural methods were superior to chemical methods.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1 Vs. T_2)

No significant difference was observed in the mean weight of grain per ear between these two cultural methods.

4. Time of application of herbicide (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

The different times of application of herbicides viz., Pre-emergence, pre and post-emergence and post-emergence was compared. No significant difference was found between the times of application.

5. Between herbicides (T_3, T_4 and T_5 Vs. T_6 Vs. T_7, T_8 and T_9)

Table 28. Comparison of herbicides

Herbicides	Mean weight of grain per ear in gm.	SE_D	C.D. (P=0.05)
Ramrod	27.60		
		4.19	8.803
2,4-D	30.60		
		2.96	6.42
Atrazine	55.90		

Conclusion: Atrazine 2,4-D Ramrod

The different herbicides viz., 2,4-D, ramrod and atrazine produced significant difference in the weight of grain per ear

Table 29. Comparison of treatment means (Straw per plant)

Treatments	Mean straw per plant in gr.	SE_D	C.D. (P=0.05)
T_0 - Control	77.81		
T_1 - Hoeing and weeding	111.16		
T_2 - Hand weeding	122.28		
T_3 - 2,4-D pre-emergence	105.60		
T_4 - 2,4-D pre+post-emergence	88.93	11.91	25.02
T_5 - 2,4-D post-emergence	83.37		
T_6 - Ramrod pre-emergence	97.35		
T_7 - Atrazine pre-emergence	155.63		
T_8 - Atrazine pre+post-emergence	133.40		
T_9 - Atrazine post-emergence	133.60		

Conclusion: T_7 T_9 T_8 T_2 T_1 T_3 T_4 T_6 T_5 T_0

Table 32. Comparison of treatment means (Plant establishment)

Treatments	Mean number of plants per metre row	SE_D	C.D. (P=0.05)
T_0 - Control	1.166		
T_1 - Hoeing and weeding	5.00		
T_2 - Hand weeding	4.00		
T_3 - 2,4-D pre-emergence	1.66		
T_4 - 2,4-D pre+post-emergence	1.00	0.5157	1.083
T_5 - 2,4-D post-emergence	1.50		
T_6 - Ramrod pre-emergence	1.16		
T_7 - Atrazine pre-emergence	5.833		
T_8 - Atrazine pre+post-emergence	5.166		
T_9 - Atrazine post-emergence	4.330		

Conclusion: T_7 T_8 T_1 T_9 T_2 T_3 T_5 T_6 T_0 T_4

at P = 0.01. Atrazine was superior to both 2,4-D and ramrod in increasing the grain weight, 2,4-D and ramrod were on par with each other.

6. Interaction of herbicides with times of application

The interaction effects of herbicides 2,4-D and atrazine with times of application were not significant.

i) Thousand grain weight

Data on thousand grain weight were analysed statistically and the analysis of variance presented (Appendix IX). No significant difference in thousand grain weight was found among the different treatments.

ii) Yield of straw per plant

Data on yield of the straw per plant were analysed statistically and the analysis of variance presented (Appendix X). The different treatment effects were found to be significant at P = 0.01.

The pre-emergence application of atrazine was superior to the cultural methods in increasing the straw yield (Table 29). Atrazine treatments, the cultural methods and pre-emergence application of 2,4-D were significantly superior to control. The differences between times of application was not significant either in atrazine or in 2,4-D. Ramrod and post-emergence applications of 2,4-D were not superior to control.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 30. Comparison of control with rest

Treatments	Mean weight of straw per plant in gm	Sd_D	C.D. (P=0.05)
Control	77.81	8.88	18.656
Rest	113.48		

Conclusion: Rest Control

The difference between control and rest of the treatments was significant at P = 0.01 indicating that the different methods of weed control adopted increased the straw yield of individual plants over the unweeded control.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

The different cultural and chemical methods adopted did not differ significantly in straw yield per plant, showing that the weed control by chemical methods were as good as the conventional cultural methods.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1Vs.T_2)

No significant difference was found in the straw yield between the two cultural methods of weed control viz., hoeing and weeding by hand hoe and hand pulling of weeds, suggesting that both the methods were equal.

4. Time of application of herbicide (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

The different times of application of herbicides viz., pre-emergence, pre and post-emergence and post-emergence did not produce any significant difference in straw yield per plant.

5. Between herbicides (T_3, T_4 and T_5 Vs. T_6Vs.T_7, T_8 and T_9)

Table 31. Comparison of herbicides

Herbicides	Mean weight of straw per plant in gm	SE_m	C.D. (P=0.05)
Ramrod	87.35	9.78	20.54
2,4-D	92.63	7.03	14.77
Atrazine	140.87		

Conclusion: Atrazine 2,4-D Ramrod

The difference in straw yield per plant between 2,4-D, ramrod and atrazine was significant at P = 0.01. Atrazine was superior to both 2,4-D and ramrod in increasing the straw yield per plant while 2,4-D and ramrod behaved alike.

6. Interaction of herbicides with times of application

The interaction effects of herbicides 2,4-D and atrazine with times of application were not significant.

B. Field observations

i) Crop emergence: The data on crop emergence recorded in the field were analysed statistically and the analysis of variance presented (Appendix XI). The different treatments did not differ significantly with respect to germination of sorghum.

ii) Plant establishment: Data on plant establishment taken on full flowering stage of the crop were analysed statistically and the analysis of variance presented (Appendix XII). The different treatment effects were found significant at P=0.01.

Applications of atrazine and the two cultural methods were significantly superior to rest of the treatments (Table 32). Pre-emergence application of atrazine was significantly superior to its post-emergence treatment and the hand weeded plot. All the treatments of 2,4-D and treatment of ramrod were not better than the unweeded control.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 33. Comparison of control with rest

Treatments	Mean number of plants per metre row	SE_D	C.D. (P=0.05)
Control	1.166	0.384	0.8067
Rest	3.30		

Conclusion: Rest Control

The difference between control and rest of the treatments was significant at P = 0.01 indicating that the unchecked growth of weeds was detrimental to the establishment of sorghum.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

Table 34. Comparison of cultural with chemical

Treatments	Mean number of plants per metre row	SE_D	C.D. (P=0.05)
Cultural	4.50	0.292	0.613
Chemical	2.95		

Conclusion: Cultural Chemical

Between the cultural and chemical methods the difference in plant establishment was significant at P = 0.01. The cultural methods were superior to the chemical methods.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1Vs.T_2)

No significant difference was found in plant establishment between these two cultural methods of weed control.

4. Time of application of herbicide (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

The different times of application of herbicides viz., pre-emergence, pre and post-emergence and post-emergence did not produce any significant difference in plant establishment.

Table 36. Crop injury

Treatments	Three weeks after sowing	Seven weeks after sowing
T_0 - Control	0.0	0.0
T_3 - 2,4-D pre-emergence	0.0	0.0
T_4 - 2,4-D pre+post-emergence	0.0	0.0
T_5 - 2,4-D post-emergence	0.0	0.0
T_6 - Ramrod pre-emergence	0.0	0.0
T_7 - Atrazine pre-emergence	0.0	0.0
T_8 - Atrazine pre+post emergence	0.0	0.0
T_9 - Atrazine post-emergence	0.0	0.0

Ratings: 0 = No visible effect

5 = Severe scorching of stem and leaves

10 = Complete mortality

5. Between herbicides (T_3, T_4 and T_5 Vs. T_6 Vs. T_7 , T_8 and T_9)

Table 35. Comparison of herbicides

Herbicides	Mean number of plants per metre row	SE_D	C.D. (P=0.05)
Ramrod	1.166	0.421	0.884
2,4-D	1.390	0.297	0.623
Atrazine	5.110		

Conclusion: Atrazine 2,4-D Ramrod

Comparison of the effects of different herbicides 2,4-D, ramrod and atrazine showed that the difference in plant establishment was significant at P = 0.01. Atrazine was superior to both 2,4-D and ramrod, while 2,4-D and ramrod were on par.

6. Interaction of herbicides with times of application

The interaction effects of herbicides 2,4-D and atrazine with times of application were not significant.

iii) Crop injury: The sorghum crop did not show any visible effect due to the post-emergence sprays of 2,4-D and atrazine either at the six leaf stage or at the shade out period (Table 36). The pre-emergence sprayed plots also did not show any symptoms of crop injury during the crop growth period.

Table 37. Comparison of treatment means (Grain yield per plot)

Treatments	Grain per plot in Kg.	SE_D	C.D. (P=0.05)
T_0 - Control	0.860		
T_1 - Hoeing and weeding	11.690		
T_2 - Hand weeding	9.230		
T_3 - 2,4-D pre-emergence	1.540		
T_4 - 2,4-D pre+post emergence	0.893	1.968	4.134
T_5 - 2,4-D post-emergence	1.535		
T_6 - Ramrod pre-emergence	1.073		
T_7 - Atrazine pre-emergence	11.805		
T_8 - Atrazine pre+post emergence	9.335		
T_9 - Atrazine post-emergence	8.630		

Conclusion: T_7 T_1 T_8 T_2 T_9 T_3 T_5 T_6 T_4 T_0

Table 41. Comparison of treatment means (Straw yield per plot)

Treatments	Straw yield in Kg.	SE_D	C.D. (P=0.05)
T_0 - Control	4.335		
T_1 - Hoeing and weeding	41.576		
T_2 - Hand weeding	39.019		
T_3 - 2,4-D pre-emergence	9.949		
T_4 - 2,4-D pre+post-emergence	4.824	6.2	13.026
T_5 - 2,4-D post-emergence	6.169		
T_6 - Ramrod pre-emergence	5.520		
T_7 - Atrazine pre-emergence	58.584		
T_8 - Atrazine pre+post emergence	47.579		
T_9 - Atrazine post-emergence	48.924		

Conclusion: T_7 T_9 T_8 T_1 T_2 T_3 T_5 T_6 T_4 T_0

iv) Grain yield per plot: Data on grain yield per plot were analysed and the analysis of variance presented (Appendix XIII). The different treatment effects were found significant at P = 0.01.

A comparison of the treatment means revealed that the three methods of application of atrazine and the two cultural methods were on par and superior to all the other treatments (Table 37). The applications of 2,4-D and ramrod were not superior to control. The difference between times of application was not significant either in atrazine or in 2,4-D.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 38. Comparison of control with rest

Treatments	Grain per plot in Kg	SE_D	C.D.(P=0.05)
Control	0.860	1.465	3.077
Rest	6.193		

Conclusion: Rest Control

There was significant difference between control and rest of the treatments at P = 0.01 indicating that the different methods of weed control adopted increased the grain yield of the crop.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

Table 39. Comparison of cultural with chemical

Treatments	Grain per plot in Kg	SE_D	C.D.(P=0.05)
Cultural	10.460	1.114	2.340
Chemical	4.973		

Conclusion: Cultural Chemical

Comparison of the cultural methods and the chemical methods showed that they produced significant difference in grain yield at P = 0.01. The cultural methods were superior to chemical methods in increasing grain yield.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1Vs.T_2)

No significant difference was found in grain yield between these two cultural methods of weed control. The result indicated that both the methods were equally effective in increasing grain yield.

4. Time of application of herbicide (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

A comparison of the different times of application of herbicide viz., pre-emergence, pre and post-emergence and post-emergence showed no significant difference between them.

5. Between herbicides (T_3, T_4 and T_5 Vs. T_6 Vs. T_7, T_8 and T_9)

Table 40. Comparison of herbicides

Herbicides	Grain per plot in Kg	SE_D	C.D. (P=0.05)
Ramrod	1.073	1.605	3.372
2,4-D	1.322	1.132	2.378
Atrazine	9.923		

Conclusion: Atrazine 2,4-D Ramrod

The different herbicides, 2,4-D, ramrod and atrazine produced differences in grain yield significant at P = 0.01. Atrazine was superior to both 2,4-D and ramrod in increasing grain yield whereas 2,4-D and ramrod behaved alike.

6. Interaction of herbicides with times of application

The interaction effects of herbicides 2,4-D and atrazine with times of application were not significant.

v) Straw yield per plot: Data on straw yield per plot were analysed and the analysis of variance presented (Appendix XIV). The different treatment effects were found significant at P = 0.01.

All the three methods of application of atrazine and the two cultural methods were superior to the rest of the treatments (Table 41). Pre-emergence application of atrazine was superior to the cultural methods. The difference between

the times of application was not significant for atrazine and 2,4-D. The different applications of 2,4-D and ramrod were not significantly superior to control.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 42. Comparison of control with rest

Treatments	Yield of straw in Kg	SE_D	C.D.(P=0.05)
Control	4.335	4.620	9.706
Rest	29.127		

Conclusion: Rest Control

There was significant difference between control and rest of the treatments at P=0.01 indicating that the different methods of weed control adopted increased straw yield per plot.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

Table 43. Comparison of cultural with chemical

Treatments	Straw yield in Kg	SE_D	C.D.(P=0.05)
Cultural	40.287	3.514	7.3829
Chemical	25.935		

Conclusion: Cultural Chemical

The difference between cultural and chemical methods was highly significant. The cultural methods were superior to chemical methods in increasing the straw yield.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1 Vs. T_2)

No significant difference was found in straw yield between these two cultural methods of weed control. Both methods were equally effective.

4. Time of application of herbicide (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

A comparison of the times of application of herbicides viz., pre-emergence, pre and post-emergence and post-emergence showed no significant difference in straw yield.

5. Between herbicides (T_3, T_4 and T_5 Vs. T_6 Vs. T_7, T_8 and T_9)

Table 44. Comparison of herbicides

Herbicides	Mean yield of straw in Kg	SE_D	C.D. (P=0.05)
Ramrod	5.520	3.690	7.752
2,4-D	6.980	3.579	7.514
Atrazine	55.029		

Conclusion: Atrazine 2,4-D Ramrod

Herbicides atrazine, 2,4-D and ramrod produced highly significant difference in straw yield per plot. Atrazine was superior to both 2,4-D and ramrod. The difference between 2,4-D and ramrod was not significant.

6. Interaction of herbicides with times of application

The interaction effects of herbicides 2,4-D and atrazine with times of application were not significant.

Table 45. Proportion of weed species in control

Name of weed species	Percentage of total population	
	45th day	75th day
Dicots:		
Trianthema portulacastrum	98.00	96.78
Digera arvensis	0.19	1.07
Amaranthus viridis	...	0.35
Datura fastuosa	...	0.35
Sedges:		
Cyperus rotundus	0.78	...
Grasses:		
Echinochloa colonum	0.39	0.71
Other grasses	0.58	0.71

Table 46. Survival of weeds in the treated plots on 75th day

Treatments	Percentage of total population		
	Dicots	Cyperus	Grasses
T_0 - Control	98.57	..	1.43
T_1 - Hoeing and weeding	95.17	1.60	3.21
T_2 - Hand pulling	84.35	9.90	5.75
T_3 - 2,4-D pre-emergence	100.00	..	..
T_4 - 2,4-D pre+post-emergence	100.00	..	..
T_5 - 2,4-D post-emergence	96.12	..	3.88
T_6 - Ronrod pre-emergence	98.70	1.30	..
T_7 - Atrazine pre-emergence	92.47	1.07	6.46
T_8 - Atrazine pre+post emergence	46.34	21.95	31.70
T_9 - Atrazine post-emergence	35.29	5.88	58.82

C. Weed study

i) Weed species: The relative proportions of different weed species recorded in the control plots are furnished (Table 45). Trianthema portulacastrum was the most dominant weed in the field.

In the treated plots (Table 46) dicot weeds, mostly Trianthema portulacastrum dominated in the control, 2,4-D and ramrod treated plots while grasses and cyperus dominated in the atrazine treated plots.

ii) (a) Weed population on 45th day: Data on number of weeds taken on 45th day were analysed and the analysis of variance presented (Appendix XV). The different treatment effects were found significant at P = 0.01.

All the methods of application of atrazine and hoeing and weeding significantly reduced the weed population than rest of the treatments (Table 47). Weed population in the hand weeded, 2,4-D and ramrod treated plots were similar to that in the control plot.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 46. Comparison of control with rest

Treatments	Mean number of weeds per quadrat	SE_D	C.D. (P=0.05)
Control	170.33	17.91	37.628
Rest	98.07		

Conclusion: Rest Control

Table 47. Comparison of treatment means (Weed population on 45th day)

Treatments	Mean number of weeds per quadrat	SE_D	C.D. (P=0.05)
T_0 - Control	170.33		
T_1 - Hoeing and weeding	58.33		
T_2 - Hand pulling	139.33		
T_3 - 2,4-D pre-emergence	145.33		
T_4 - 2,4-D pre+post emergence	166.00	24.032	50.49
T_5 - 2,4-D post emergence	164.66		
T_6 - Ramrod pre-emergence	154.33		
T_7 - Atrazine pre-emergence	9.33		
T_8 - Atrazine pre+post emergence	20.33		
T_9 - Atrazine post-emergence	25.00		

Conclusion: T_9 T_7 T_8 T_1 T_2 T_3 T_6 T_5 T_4 T_0

Table 51. Comparison of treatment means (Weed population on 75th day

Treatments	Mean number of weeds per quadrat	SE_D	C.D. (P=0.05)
T_0 - Control	93.33		
T_1 - Hoeing and weeding	124.30		
T_2 - Hand pulling	104.33		
T_3 - 2,4-D pre-emergence	79.33		
T_4 - 2,4-D pre+post emergence	75.33	18.58	39.036
T_5 - 2,4-D post-emergence	68.60		
T_6 - Ramrod pre-emergence	77.33		
T_7 - Atrazine pre-emergence	31.00		
T_8 - Atrazine pre+post emergence	13.60		
T_9 - Atrazine post-emergence	11.30		

Conclusion: T_9 T_8 T_7 T_5 T_4 T_6 T_3 T_0 T_2 T_1

The difference between control and rest of the treatments was highly significant indicating the effect of weed control methods in reducing weed population.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

The different cultural and chemical methods of weed control adopted did not produce significant difference in weed population. The result indicate that weed control by chemical and cultural methods were equally effective.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1Vs.T_2)

Table 49. Comparison of hand weeding with hoeing and weeding

Treatments	Mean number of weeds per quadrat	SE_D	C.D. (P=0.05)
Hoeing and weeding	58.33	24.032	50.49
Hand pulling	139.33		

Conclusion: Hoeing and weeding Hand pulling

The difference between hoeing and weeding and removal of weeds by hand pulling was significant at P = 0.01. Hoeing and weeding by hand hoe was superior to hand pulling in reducing weed population.

4. Time of application of herbicide (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

A comparison of the different times of application of herbicides viz., pre-emergence, pre and post-emergence and

post-emergence did not reveal any significant difference in weed population.

5. Between herbicides (T_3, T_4 and T_5 Vs. T_6 Vs. T_7, T_8 and T_9)

Table 50. Comparison of herbicides

Herbicides	Mean number of weeds per quadrat	SED	C.D. (P=0.05)
Ramrod	154.33	19.62	41.22
2,4-D	158.66	13.87	29.14
Atrazine	18.22		

Conclusion: Atrazine Ramrod 2,4-D

Among the different herbicides, atrazine was the most efficient in reducing weed population.

6. Interaction of herbicides with times of application

The interaction effects of herbicides 2,4-D and atrazine with times of application were not significant.

ii) (b) Weed population on 75th day: Data on weed population taken on 75th day were analysed and the analysis of variance presented (Appendix XVI). The different treatment effects were significant at P = 0.01.

The applications of atrazine alone significantly reduced weed population than the unweeded control (Table 51). The differences among atrazine applications were not significant. Weed population in the 2,4-D and ramrod treated plots were less than that in the hand hoed plot.

The following independent comparisons were,

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

There was no significant difference in weed population between control and rest of the treatments at the second count.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

Table 52. Comparison of cultural with chemical

Treatments	Mean number of weeds per quadrat	SE_D	C.D.(P=0.05)
Cultural	114.31	10.53	22.12
Chemical	50.95		

Conclusion: Chemical Cultural

The two methods of weed control produced a difference in weed population which was significant at P = 0.01. The chemical methods were more effective than cultural methods in reducing weed population.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1 Vs. T_2)

These two methods did not produce any significant difference in weed population.

4. Time of application of herbicide (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

No significant difference was found in weed population between the different times of application of herbicides viz., pre-emergence, pre and post-emergence and post-emergence.

Table 54. Comparison of treatment means (Weed weight on 45th day)

Treatments	Weed weight in gm	SE_D	C.D. (P=0.05)
T_0 - Control	425.30		
T_1 - Hoeing and weeding	96.30		
T_2 - Hand pulling	208.00		
T_3 - 2,4-D pre-emergence	419.30		
T_4 - 2,4-D pre+post emergence	425.00	56.22	118.118
T_5 - 2,4-D post emergence	318.00		
T_6 - Ramrod pre-emergence	405.30		
T_7 - Atrazine pre-emergence	16.60		
T_8 - Atrazine pre+post emergence	11.60		
T_9 - Atrazine post-emergence	8.60		

Conclusion: T_9 T_8 T_7 T_1 T_2 T_5 T_6 T_3 T_4 T_0

Table 59. Comparison of treatment means (Weed weight on 75th day)

Treatments	Weed weight in gm.	SE_D	C.D. (P=0.05)
T_0 - Control	444.30		
T_1 - Hoeing and weeding	20.00		
T_2 - Hand pulling	39.00		
T_3 - 2,4-D pre-emergence	449.60		
T_4 - 2,4-D pre+post-emergence	405.30	49.10	103.15
T_5 - 2,4-D post-emergence	338.30		
T_6 - Ramrod pre-emergence	358.30		
T_7 - Atrazine pre-emergence	26.60		
T_8 - Atrazine pre+post emergence	17.00		
T_9 - Atrazine post-emergence	14.00		

Conclusion: T_9 T_8 T_1 T_7 T_2 T_5 T_6 T_4 T_0 T_3

5. Between herbicides (T_3, T_4 and T_5 Vs. T_6 Vs. T_7, T_8 and T_9)

Table 53. Comparison of herbicides

Herbicides	Mean number of weeds per quadrat	SE_D	C.D.(P=0.05)
Ramrod	77.33	15.17	31.87
2,4-D	74.42	10.72	22.52
Atrazine	18.63		

Conclusion: Atrazine 2,4-D Ramrod

The differences in weed population between herbicide application of ramrod, 2,4-D and atrazine was highly significant. Atrazine was superior to both 2,4-D and ramrod in reducing weed population.

6. Interaction of herbicides with times of application

The interaction effects of herbicides 2,4-D and atrazine with times of application were not significant.

iii) (a) Weight of weeds on 45th day: Data on dry weight of weeds recorded on the 45th day were analysed and the analysis of variance presented (Appendix XVII). The different treatment effects were found significant at P=0.01.

All the treatments with atrazine were on par and were superior to hand weeding, other herbicide applications and control (Table 54). The cultural methods also significantly reduced the weed weight than the control. Treatments of 2,4-D and ramrod were not superior to control.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 55. Comparison of control with rest

Treatments	Weed weight in gm	SE_D	C.D.(P=0.05)
Control	425.30	41.9	88.03
Rest	212.10		

Conclusion: Rest Control

There was significant difference in weed weight between control and rest of the treatments at P = 0.01 indicating that the weed control methods adopted were effective in reducing the weight of the weeds.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

Table 56. Cultural with chemical

Treatments	Weed weight in gm	SE_D	C.D.(P=0.05)
Cultural	152.15	31.8	66.81
Chemical	229.23		

Conclusion: Cultural Chemical

The comparison revealed that the cultural methods were superior to the chemical methods in reducing weed weight.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1 Vs. T_2)

No significant difference was observed in the dry weight of weeds between these two cultural methods indicating that both the methods were equally effective.

4. Time of application of herbicide (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

Table 57. Comparison of times of application of herbicides

Time of application	Weed weight in gm	SE_D	C.D. (P=0.05)
Pre-emergence	280.40	36.2	76.00
Pre + post-emergence	218.30	38.7	81.30
Post-emergence	163.30		

Conclusion:

Post-emergence Pre+post-emergence Pre-emergence

A comparison of the different times of application of herbicides viz., pre-emergence, pre and post-emergence and post-emergence revealed that post-emergence application significantly reduced weed weight than the pre-emergence application.

5. Between herbicides (T_3, T_4 and T_5 Vs. T_6 Vs. T_7, T_8 and T_9)

Table 58. Comparison of herbicides

Herbicides	Weed weight in gm	SE_D	C.D. (P=0.05)
Ramrod	405.30	45.9	96.43
2,4-D	387.40	32.4	68.07
Atrazine	12.20		

Conclusion: Atrazine 2,4-D Ramrod

The differences in weed weight between herbicides were highly significant. Atrazine was superior to both 2,4-D and ramrod. Herbicides 2,4-D and ramrod were on par.

6. Interaction of herbicides with times of application

The interaction effects of herbicides 2,4-D and atrazine with times of application were not significant.

iii) (b) Weight of weeds on 75th day: Data on dry weight of weeds recorded on 75th day were analysed and the analysis of variance presented (Appendix XVIII). The different treatment effects were found to be significant at P = 0.01.

All the treatments of atrazine and the two cultural methods were on par and effective than all other treatments in reducing weed weight (Table 59). The post-emergence application of 2,4-D was better than its pre-emergence application and control but much inferior to atrazine and cultural methods.

The following independent comparisons were made.

1. Control Vs. Rest (T_0 Vs. T_1 to T_9)

Table 60. Comparison of control with rest

Treatments	Weed weight in gm	SE_D	C.D.(P=0.05)
Control	444.3	36.60	76.80
Rest	185.5		

Conclusion: Rest Control

There was highly significant difference between the treated and control plots indicating that the weed control treatments adopted were effective in reducing weed weight.

2. Cultural Vs. Chemical methods (T_1 and T_2 Vs. T_3 to T_9)

Table 61. Comparison of cultural with chemical

Treatments	Weed weight in gm	SE_D	C.D.(P=0.05)
Cultural	29.50	27.8	58.40
Chemical	230.00		

Conclusion: Cultural Chemical

The difference in weed weight between the cultural methods and chemical methods was highly significant and the cultural methods were superior to chemical methods.

3. Hand pulling Vs. hoeing and weeding by hand hoe (T_1Vs.T_2)

The comparison revealed no significant difference in weed weight between the two cultural methods. Both the methods were equally effective.

4. Time of application of herbicides (T_3, T_6 and T_7 Vs. T_4 and T_8 Vs. T_5 and T_9)

Table 62. Comparison of times of herbicide application

Times of application	Weed weight in gm	SE_D	C.D.(P=0.05)
Pre-emergence	278.60	31.7	66.6
Pre + post-emergence	211.10	34.7	72.9
Post-emergence	176.10		

Conclusion: Post-emergence Pre+post-emergence Pre-emergence

Significant difference in weed weight was observed between the different times of application of herbicides. Post-emergence and a combination of pre-emergence and post-emergence was superior to pre-emergence treatment.

5. Between herbicides (T_3, T_4 and T_5Vs. T_6 Vs. T_7, $T_8$and T_9)

Table 63. Comparison of herbicides

Herbicides	Weed weight in gm	SE_D	C.D.(P=0.05)
Ramrod	358.3	40.1	84.25
2,4-D	397.7	28.3	59.45
Atrazine	19.2		

Conclusion: Atrazine Ramrod 2,4-D

The herbicides, 2,4-D, ramrod and atrazine produced significant differences in weed weight. The herbicide, atrazine was most efficient in reducing weed weight than the other two. Difference between ramrod and 2,4-D was not significant.

6. Interaction of herbicides with times of application

The interaction effects of herbicides 2,4-D and atrazine with times of application were not significant.

iv) Weed control: The weed control is expressed in terms of the percentage reduction in weed weight over the control (Table 64).

Table 64. Weed Control

Treatments	Control on 45th day	Control on 75th day
T_0 - Control	..	..
T_1 - Hoeing and weeding	77.5	95.5
T_2 - Hand pulling	51.1	91.3
T_3 - 2,4-D pre-emergence	1.5	- 1.2
T_4 - 2,4-D pre+post emergence	0.1	8.8
T_5 - 2,4-D post-emergence	25.3	23.9
T_6 - Ramrod pre-emergence	4.8	19.4
T_7 - Atrazine pre-emergence	96.1	94.0
T_8 - Atrazine pre+post-emergence	97.3	96.2
T_9 - Atrazine post-emergence	98.0	96.8

Table 66. Linear regressions

Details	45th day after sowing	75th day after sowing
b values:		
Grain yield on weed weight	-0.0217**	-0.02202**
Straw yield on weed weight	-0.10377**	-0.10034**
Linear regression equations		
Grain yield Y on weed weight X	Y=10.725-0.0217X	Y=10.315-0.02202X
Straw yield Y on weed weight X	Y=50.871-0.1037X	Y=47.859-0.10034X

** Significant at P=0.01 level

v) Relationship of weed growth with crop yield: The simple correlation coefficients of grain and straw yields with the weed growth are given in table. 65.

Table 65. Simple correlation

Between	r values	
	45th day after sowing.	75th day after sowing.
Weed weight and grain yield	- 0.8015**	- 0.8666**
Weed weight and straw yield	- 0.8094**	- 0.8957**
Weed population and grain yield	- 0.6893**	- 0.2375 N.S.

** Significant at P = 0.01

The association between weed growth and grain and straw yields is very strong as revealed by the highly significant correlations.

The high significance of linear regression coefficient of the grain and straw yields on weed weight (Table 66) indicate that weed growth exerts significant negative influence on the grain and straw yields of the crop. The extent of this influence has been utilized to predict the approximate yields of grain and straw for a given extent of weed growth by fitting linear regression equations.

D. Economics of weed control

The economics of weed control by different methods is furnished in Table 67.

Table No.67

Economics of different weed control methods per hectare over control

Treatments	Extra grain yield over control in Kg	Extra straw yield over control in Kg	Value of extra produce Rs./ hectare	Cost of weed control Rs.	Cost of preparation of extra produce Rs.	Total cost Rs.	Net profit per hectare Rs.	Yield of grain in Kg/ rupee invested in weed control
T_0 - Control	..	..	..	..	..	..	..	..
T_1 - Hoeing and weeding	1790.0	6155.0	1264.00	150.00	268.50	418.50	845.50	11.933
T_2 - Hand pulling	1383.0	5732.0	1035.50	180.00	207.50	387.50	648.00	7.683
T_3 - 2,4-D pre-emergence	112.0	928.0	112.00	33.70	16.80	50.50	61.50	3.323
T_4 - 2,4-D pre+post-emergence	5.0	81.0	7.30	73.70	..	73.70	-66,40	0.067
T_5 - 2,4-D post- emergence	112.0	303.0	75.80	40.00	16.80	56.80	19.00	2.800
T_6 - Ramrod pre-emergence	35.0	196.0	29.50	199.93	5.25	205.20	-175.70	0.175
T_7 - Atrazine pre-emergence	1809.0	8966.0	1442.50	115.60	271.35	387.00	1055.50	15.648
T_8 - Atrazine pre + post-emergence	1400.0	7147.0	1129.00	231.20	210.00	441.20	687.80	6.055
T_9 - Atrazine post-emergence	1284.0	7371.0	1084.20	166.00	192.60	358.60	725.60	7.735

Cost of grain .. Rs.50.00 per quintol

Cost of straw .. Rs.60.00 per ton

Cost of processing extra produce .. Rs.15.00 per quintol

All the methods of weed control except pre-emergence application of ramrod and pre and post-emergence application of 2,4-D were profitable (Fig.11). Maximum net profit was obtained from pre-emergence application of atrazine followed by hoeing and weeding. Weed control by atrazine application and cultural methods resulted in sizable profits.

In comparing the extra yield of grain per rupee invested in weed control by different methods, pre-emergence application of atrazine gave maximum return of 15.648 Kg. of grain per rupee (Fig.12).

The expenditure for various items were calculated per hectare on the following basis.

Hoeing and weeding once 50 women per hectare at Rs.1.50/woman, for 2 operations	.. Rs.150-00
Hand pulling of weeds once 60 women per hectare at Rs.1.50/woman, for 2 operations	.. Rs.180-00

Cost of herbicides

2,4-D (Blodex-A)	.. Rs. 9-00/Kg
Ramrod-65	.. Rs. 27-55/Kg
Atrazine U.P.	.. Rs. 45-00/Kg

Cost of spraying per hectare once

6 men at Rs.2.30/each	.. Rs.13-80
Hire charge of 4 sprayers	.. Rs. 1-00
	Rs.14-80

E. Residual effects

i) Herbicide residue in crop: Chloroform extract of sorghum grain and straw at the time of harvest was analysed for atrazine

Table 68. Sample absorbance readings

Sample	E_{225}	E_{240}	E_{255}	Δ
T_7	0.94	0.68	0.55	-0.065
T_8	1.60	1.00	0.72	-0.160
T_9	0.56	0.43	0.37	-0.035
T_0	0.645	0.49	0.402	-0.033
Blank of reagents	0.565	0.415	0.290	-0.012
50 u gm	0.522	0.578	0.267	0.184
100 u gm	0.602	0.686	0.292	0.241
150 u gm	0.620	0.950	0.290	0.495
200 u gm	1.04	1.35	0.49	0.585

$$\Delta = E_{240} - \frac{(E_{255} + E_{225})}{2}$$

Table 69. Observations on subsequent crop

Treatments	Ragi	Cotton
T_0 - Control	0.0	0.0
T_3 - 2,4-D pre-emergence	0.0	0.0
T_4 - 2,4-D pre + post-emergence	0.0	0.0
T_5 - 2,4-D post-emergence	0.0	0.0
T_6 - Ramrod pre-emergence	0.0	0.0
T_7 - Atrazine pre-emergence	0.0	0.0
T_8 - Atrazine pre + post-emergence	0.0	0.0
T_9 - Atrazine post-emergence	0.0	0.0

Rating: 0 = No visible effect; 10 = Complete mortality

residue by the spectrophotometric method, no atrazine residue was detected. The readings of the treated crop sample was comparable with that of the untreated crop sample and blank of the reagents used (Table 68).

ii) Fertility of sorghum seeds: There was no significant differences in the germination percentages of the sorghum seeds collected from the herbicide treated and hand weeded plots (Appendix XIX). All the samples showed normal germination though the germination of seeds from the 2,4-D treated plots was slightly less than the rest.

iii) Fertility of weed seeds: The difference in the germination percentage of the Trianthema portulacastrum seeds collected from the different herbicide treated and hand weeded plots was not statistically significant (Appendix XX). However, the germination percentage of the seeds varied from 26 per cent in the 2,4-D pre-emergence treated plot to 38.6 per cent in the atrazine treated plot.

iv) Effect of herbicide application on subsequent crop: In the case of ragi, raised in the differently treated soils there was no difference either in seed emergence or plant growth up to flowering (Table 69). Cotton seeds (M.C.U.3) sown in the differently treated soil gave uniform emergence and there was no difference in seedling growth up to 20 days.

DISCUSSION

DISCUSSION

The results of observations made in this trial, evaluating the herbicides and comparing them with the cultural methods reveal that the herbicide atrazine compares favourably with the cultural methods and in certain aspects even excel them. The results pertaining to plant characters, yield, weed control, weed competition and its relationship with the crop, economics and the after effects of herbicide use are discussed below.

A. PLANT CHARACTERS

1) Plant height: The results showed that weed competition lead to a reduction in the height of sorghum. Burnside and Wicks (1965) reported reduction in sorghum height in the unweeded control. Similar observations were made by Nazamuddin and Rehman (1960) in maize and Verma and Bharadwaj (1963) in sugarcane.

Among the different weed control treatments adopted, plants in the plots receiving pre-emergence application of atrazine was taller than those in the cultural plots. Phillips and Ross (1965) observed that sorghum plants in the atrazine and propazine treated plots were one and two inches taller than those on the cultivated plots. George et al. (1967) reported increased plant height in sorghum over the hand weeded control.

Though both the atrazine treatments and the cultural methods were effective in controlling weeds, the increases of sorghum height in the atrazine pre-emergence treated plots might be due

to the weed free condition provided by the treatment (Plate I) and the weed competion suffered by the plants in the cultural plots up to the first weeding.

Post-emergence applications of 2,4-D and the treatment of ramrod were not superior to control. It might be inferred that this reduction in height was due to the ineffectiveness of the treatments to control weeds.

The chemical and cultural methods of weed control were found to have similar effects on plant height. Burnside and Wicks (1965) reported that cultivations were able to reduce weed stands to the extent that weeds did not reduce sorghum height.

Plant height in the hand hoed plot was on par with hand weeded plot indicating that presence or absence of weeds alone affected the height of sorghum and intercultivation received along with hand hoeing had no beneficial effect.

Atrazine significantly enhanced plant height over 2,4-D and ramrod. Such effect of atrazine over other herbicides was reported by Bodade (1965) in sorghum. Pre-emergence, post-emergence or the combination of two did not affect the plant height. But within herbicides the difference between times of application was significant in 2,4-D.

Thus, weed control increased the plant height in sorghum and pre-emergence application of atrazine was the best (Fig.2).

ii) Number of leaves: The variation in the mean number of leaves produced in the differently treated plots showed that weed infestation of the field affected the leaf production in sorghum and that the weed control methods were beneficial to enhance leaf production.

Atrazine was superior to 2,4-D in enhancing leaf number. Lapchenkov (1966) concluded from a herbicide trial that applications of atrazine and simazine were the best among herbicides which increased yields of fresh material in fodder sorghum. The non significant difference between the cultural and chemical methods indicated that the use of herbicides for weed control in sorghum was as effective as the conventional methods and that the herbicides had no adverse effect on leaf production. Interculture did not have any benefit on the crop other than weeding.

The time of application of herbicides had no effect on this character. However, the superiority of pre-emergence treatment of atrazine over hand weeded plot was confirmed.

iii) Leaf area: The weed control treatments adopted significantly influenced the leaf area of sorghum (Fig.3). Atrazine applications resulted in maximum increase of leaf area followed by cultural methods, 2,4-D and ramrod in that order. This leads to the conclusion that the leaf area of the plant was reduced by the weediness of the crop.

Atrazine was the most effective in increasing leaf area. The interaction of herbicides with time of application was

significant, since in 2,4-D pre-emergence or post-emergence was superior to its combination. The superiority of cultural methods over the other herbicides reveals that both the cultural methods were equally effective while, among the herbicides only atrazine was effective. The non significant difference between the cultural methods showed that hoeing and weeding had no benefit other than removal of weeds.

Since the vegetative characters such as plant height, leaf number and area were favourably influenced by the atrazine treatments it may be concluded that the increased plant vigour (Plate VIII) exhibited by the atrazine treated plots may be due to its effective herbicidal property.

iv) Thickness of peduncle: The thickness of the peduncle was influenced by the weed control methods tried and it was proportional to the effectiveness of the methods. The treatments of 2,4-D and ramrod though better than the control was inferior to the cultural methods.

Atrazine recorded maximum values of thickness and was the best among herbicides. The differences between times of application was not significant in any case and hence any time of application tried can be adopted for weed control. The overall superiority of the cultural methods over the chemicals may be attributed to the effectiveness of the cultural methods while among the chemicals atrazine alone was effective. George et al. (1967) observed no difference in thickness of

peduncle of sorghum between hand weeded and atrazine treated plots.

The additional tillage gained by the hand hoed plots was not beneficial to the crop and hence a tillage along with weed removal was of no use to increase the thickness of peduncle.

v) Length of earhead: The different weed control methods produced differences in the length of earhead indicating that the treatments affected the ear length (Fig.4). The mean length of ear in the treated plots were more than the unweeded plot showing that the weed infestation reduced ear length of sorghum, a character highly correlated with yield according to Ayyangar et al. (1935).

The treatments of atrazine and the cultural methods were superior to other treatments in increasing ear length. Among the herbicides, atrazine was the best and the results further revealed that any time of application of herbicide can be adopted for weed control.

The cultural and chemical methods did not produce any difference in ear length which indicated that the chemical and cultural methods were equally efficient. Lawba and Verma (1962) studying the residual effects of heavy applications of herbicides observed that the ear length of wheat remained unaffected in all the treatments.

Similar lengths of ear in the hand weeded and hoed plots indicated that intercultivation had no beneficial effect on ear length of sorghum.

vi) Breadth of earhead: The difference in the mean breadth of ear in the variously treated plots showed the effect of treatments on this character. The breadth of the ear in the treatment was more than that in the control, which indicated that weed growth lead to a reduction in the breadth of ear, a character highly correlated with yield according to Ayyangar et al. (1935). The treatments of atrazine and the cultural methods reduced weed growth to the extent however, that the breadth of the ear was not affected.

Among the herbicides, atrazine was the best and was effective when applied as pre-emergence, post-emergence or as a combination of the two. The mean breadth of ear in the cultural and chemical plots did not differ indicating that weed control by the two methods were equally effective and that the herbicide application had no adverse effect on this earhead character.

No difference in breadth of ear was noticed between the two cultural methods indicating that the additional tillage received by the hand hoed plots did not produce any effect on the earhead.

vii) Weight of the earhead: The varying degree of weed infestation in the field caused by the different weed control

methods produced corresponding difference in the weight of the ear. The mean weight of the earhead in the treatment plots was more than that of the unweeded check. Weed growth along with the crop reduced the weight of the ear and so weed control methods were beneficial to enhance the yield potential of the plant. Burnside et al. (1964) reported from an experiment on dry land sorghum at Nebraska that the weight of the individual heads was significantly more in the culturally and chemically controlled plots using atrazine than in the weedy control.

Among the different herbicides tried, atrazine significantly increased ear weight than 2,4-D and remained.

In the general comparison the cultural methods were superior to the chemical methods. However, the treatments of atrazine were on par with the cultural methods. George et al. (1967) found that the weight of the earhead of grain sorghum was not different in the atrazine treated and hand weeded plots.

Between the different times of application of herbicides, none of them significantly affected the weight of the earhead, indicating that the weed competition upto 45 days after sowing the crop did not affect the ear weight. Hence all the times of application of atrazine was equally effective.

Intercultivation given to the hand hoed plots had no beneficial effect on the earhead weight.

viii) Weight of the grain per ear: Significant differences were observed in the mean weights of grain per ear from the different treatment plots (Fig.5). The grain weight per ear was the highest in the plots where the weed control methods were most effective, thus weed competition caused a severe reduction in the yield of grain per ear. Burnside and Wicks (1965) reported that weed control treatments that did not adequately control weeds reduced sorghum seed weight per ear.

Of the different weed control methods tried, atrazine applications and the cultural methods were superior to all the other methods of weed control in increasing weight of grain per ear.

Among the herbicides, atrazine increased the grain weight per ear and any time of application tried was suitable.

The superiority of cultural weed control methods over the herbicidal methods on a whole might be attributed to the ineffective control of weeds in the 2,4-D and ramrod treated plots. Burnside and Wicks (1965) observed no difference in grain weight per ear between chemical and cultural methods when the weed control was effective.

Comparing the merits of the two cultural methods both were equally efficient in enhancing the grain weight per ear showing that tillage during the growth phase of the crop was not essential. Burnside and Wicks (1964) studying the effect of cultivations on dry land sorghum concluded that on soil types

where weeds were controlled, cultivations were neither advantageous nor necessary.

A review of the earhead characters such as the girth of peduncle, length, breadth and weight of the ear along with the mean yield of grain which were highly correlated with the ultimate yield of the crop showed that weed infestation adversely affected these characters and in all the cases atrazine treatments recorded maximum closely followed by the cultural methods of weed control. Rest of the treatments were either inferior or not better than the unweeded control.

ix) Thousand grain weight: The results of investigation revealed that the 1000-grain weight of sorghum was not affected by the presence or absence of weeds in the field. Burnside and Wicks (1965) also reported that the seed weight of sorghum was not affected by weed competition. Similar observations were made by Misra and Kumar (1962) in bajra and Martin and Tittal (1963) in barley.

The result also indicated that herbicide application for weed control did not affect the 1000-grain weight of sorghum. George et al. (1967) studying the effect of atrazine applications on different varieties of sorghum observed no difference in 1000-grain weight between the atrazine treated and hand weeded plots.

x) Yield of straw per plant: The difference in the mean straw yield between the different treatments indicated the effect

of treatments on straw yield of sorghum. The straw yield closely followed the effectiveness of the weed control treatments adopted. A high yield of straw in the treated plots than that in the unweeded plot showed that weed infestation reduced straw per plant. Burnside et al. (1964) found that the yield of fresh material in sorghum was increased by controlling weeds. Lapchenkov (1966) also obtained increased yields in fodder sorghum by weed control.

Among the effective treatments, pre-emergence application of atrazine was superior to the cultural treatments. This may be due to the early weed control made possible by the pre-emergence treatment whereas in the cultural plots the crop suffered weed competition upto the first weeding and in later stages from subsequent regrowth of weeds.

Atrazine was the best among herbicides to increase straw yields. Bodode (1965) reported similar results. The non significant difference between the times of application indicated that any time of herbicide application can be used. The results further revealed that the chemical and cultural methods were equally effective in increasing the straw yield and that the herbicide application did not affect the dry matter production of the crop. The benefit of intercultivation also was not reflected on the straw yield per plant.

B. FIELD OBSERVATIONS

i) Crop emergence: The pre-emergence application of herbicides is likely to effect germination and emergence.

A study of crop emergence was made with a view to ascertain whether the emergence of sorghum was affected by such treatments.

The results revealed that there was no difference in crop emergence between the pre-emergence treated plots and the unsprayed plots. Hence the pre-emergence application of herbicides did not cause any inhibition of emergence of sorghum. This was in agreement with the results of Bharadwaj and Verma (1961) who reported from three years data that the pre-emergence application of 2,4-D had not adversely affected emergence of wheat.

ii) Plant establishment: Significant differences in the plant population were caused by the different weed control methods. The plant establishment was maximum in the plots where weed control was effective. The presence of weeds in the field caused a reduction in plant population and hence adoption of weed control was essential to maintain the optimum crop stand. Tadulingam and Venkatanarayana (1932) observed that on account of its gregarious nature and prostrate habit Trianthema became so bad in cultivated fields that the growth of any crop was almost impossible. Burnside et al. (1964) reported that hand weeding increased density of sorghum. Sedade (1965) stated that the yield increases of sorghum associated with improved weed control were attributed to increase in plant stand. Burnside and Wicks (1965) found that weedy checks reduced sorghum stand.

Atrazine was found to be the best herbicide which retained maximum crop stand. The pre-emergence application was superior to post-emergence application of atrazine. This behaviour may be attributed to the severe early weed competition suffered by the crop till it received the post-emergence treatment. Therefore, for proper plant establishment pre-emergence application of atrazine was better.

Both the cultural methods were also effective in maintaining crop stand.

The cultural methods in general were effective in maintaining crop stand when compared with the chemical methods. The difference in crop stand between the ineffective herbicide treatments of 2,4-D and ramrod and the control was not significant which revealed that the high mortality of sorghum was due to severe competition from the aggressive weed rather than the effect of herbicide. Burnside and Wicks (1965) reported that plant establishment was not affected by cultivation or herbicide.

The results revealed that weed competition caused severe mortality of sorghum seedlings. Many workers have reported such competition between plants. Bleasdale (1960) stated that the rate at which certain weeds grow in height and leaf area enabled them to supress the growth of crop plants and eventually to kill them. Instances of phytotoxins or telitoxicity between plants which cannot be attributed to competition for water

nutrients or space have been reported by Oswald (1947), Wilderman (1948) and Martin and Pademacher (1960).

In this study it was obvious that some sort of competition reduced the stand of sorghum in the weedy plots. It was not possible to clearly distinguish whether a competition for space and nutrients or a telitoxicity of weed or a combination of the two resulted in high mortality of sorghum seedlings. This requires further investigations.

iii) Assessment of crop injury: The selectivity of a herbicide depends on its toxic effect on the weeds and its ability to leave the crop unharmed.

The results showed that none of the herbicides caused any injury to sorghum at the rates and methods of application tried. This lead to the conclusion that all the herbicide treatments were selective on sorghum though their herbicidal property vary. Albert (1961) reported that post-emergence treatment with 2,4-D at one pound on sorghum six and 12 inches tall caused no sorghum injury. Feivre Dupeigre and Rognon (1965) reported selectivity of atrazine and 2,4-D on sorghum at six leaf stage. Chamberlain et al. (1967) and Anderson and Witeworth (1967) reported selectivity of atrazine when applied as post-emergence at various stages of sorghum growth.

Post-emergence application of 2,4-D and atrazine did not cause any drift hazard on a bhendi seed crop raised three metres away from the sorghum field.

iv) Grain yield per plot: The mean grain yield per plot varied from 0.860 kilogram in the control to 11.805 kilograms in the atrazine pre-emergence treated plot (Fig.6). The variation in yield revealed the influence of weed control methods on the grain yield. Where the weed control was effective the yields were high. It was evident from the earlier sections that the weed competion lead to a reduction in the growth and yield attributes of the crop. The low grain yield in the weedy plots were the result of summation of reductions caused in the plant vigour, yield of grain per ear and plant establishment. The adverse effect of weed growth on crop yield was further projected from the significant negative correlation between the weed weight and grain yield.

Such effect of weeds on sorghum yields had been reported by many workers. Horowitz and Kletter (1963) found that weed infestation reduced grain yields of irrigated sorghum by 40 per cent. Wiese et al. (1964) reported that weed growth reduced grain yields of both irrigated and dry land sorghum.

All the three applications of atrazine and the two cultural methods were the best treatments which increased the yield over the remaining treatments and control. Similar results were produced in the weight of ear, weight of grain per ear and plant establishment.

The difference between the control and rest of the treatments taken together was also significant which focussed

the effect of weed control methods and indicated the necessity to adopt weed control measures to ensure normal yields.

Atrazine produced more yield than the other two herbicides. Considering the above aspect atrazine seemed to increase the grain yield without any adverse effect on the crop. Many workers have reported the efficiency of atrazine in controlling weeds and enhancing crop yields. Horowitz and Kletter (1963) concluded from a herbicide trial on sorghum that the grain yields from atrazine treatments were highest when compared with the standard 2,4-D post-emergence treatment. Burnside et al. (1964) reported that atrazine at one pound applied pre-emergence resulted in higher sorghum yield. Dodade (1965) also reported similar effects of atrazine.

All the three times of application of herbicide tried were equally effective and hence the study revealed that any convenient time of application of herbicide can be chosen for weed control. Burnside and Wicks (1965) found that pre-emergence application of atrazine increased grain yields. Stickler and Anderson (1965) concluded from a herbicide experiment on sorghum that atrazine applied as post-emergence resulted in the highest grain yield.

Between the chemical and cultural methods, in general, the cultural methods were found to be superior, however, George et al. (1967) observed no difference in grain yield of sorghum between hand weeded and atrazine treated plots.

Grain yields were not different in the hand weeded and hand hoed plots. This indicated that hoeing which gave an interculture in addition to weeding had no beneficial effect on the crop yield other than removal of weeds. Burnside and Wicks (1964) studying the effect of intercultivation in sorghum concluded that cultivations were neither advantageous nor necessary. Call and Sewell (1917), Bever (1958), Changule and Khuspe (1962) and Kramer (1965) also reported similar results on the yields of different crops.

v) Straw yield per plot: The difference in straw yield per plot between the treatments and between the treated and control plots indicated that weed infestation reduced straw yields and weed control was essential to obtain maximum straw yields. Burnside et al. (1964) found that hand weeding increased yield of fresh material in sorghum. Radomacher (1964) stated that weed competition caused dry weight reductions in cereals. Thakur et al. (1967) obtained high straw yields by controlling weeds in paddy.

The pattern of straw yield from the different treatments followed closely the plant establishment and the straw yield per plant. This indicated that apart from the effect of weeds, plant establishment and weight of straw per plant also contributed to the straw yield.

Pre-emergence application of atrazine produced more straw than the cultural methods of weed control. This effect might

be due to the early weed control made possible by the pre-emergence treatment. The high straw yields obtained in the atrazine treated plots over the 2,4-D and ramrod treatments also indicated the efficiency of this herbicide. Bodade (1965) reported that among the herbicides tried, atrazine produced the highest yield of straw. Lopchenkovo (1966) also reported similar effects of atrazine on fodder sorghum.

It was found that the cultural methods produced more straw than the chemical methods. This might be attributed to the ineffective weed control and consequent low yields of straw produced in the 2,4-D and ramrod treated plots. Kose and Ansorge (1963) reported that the weed control by chemical method with atrazine increased the dry matter yields of maize than the cultivated plots.

The non significant difference in straw yield between the hand weeded and hand hoed plots indicated that the tillage received by sorghum at the time of hoe weeding was not beneficial to increase the straw yield and that the tillage had no benefit other than weed removal.

C. WEED STUDY

i) Weed species: The data on the weed species of the control plot revealed that Trianthema portulacastrum, an annual dicot was the most dominant weed. The other dicots such as Digera arvensis and Amaranthus viridis were of minor importance due to their numerical insignificance. The occurrence of Cyperus rotundus and Echinochloa colanum was also sparse.

In the case of atrazine treated plots, irrespective of the time of application grass and cyperus dominated. This might be attributed to the efficient control of broad leaved weeds and its ineffectiveness on grass and cyperus at the doses tried. Similar observations on the inefficiency of atrazine on grasses have been reported from earlier investigations. Anderson (1964) from a herbicide experiment on grain sorghum stated that atrazine at two pounds per acre was the most effective herbicide except against grasses. Shivaji and Rao (1965) from a weed control trial on maize concluded that atrazine at four to eight pounds per acre controlled broad leaved and grass weeds while a two pounds rate was sufficient to control the broad leaved weeds.

In the 2,4-D pre-emergence treated plots, grass and cyperus were absent whereas broad leaved weeds were dominant. In the hand hoed and hand weeded plots also grass and cyperus were present though the dominant species was Trianthema. The very low proportion of grass and cyperus in the control plot and in the 2,4-D and ramred treated plots might be due to the smothering effect of the dominant weed Trianthema. Tadulingam and Venkatanarayana (1932) described it as one of the most dominant and aggressive weeds of cultivation under Coimbatore condition.

ii) Weed population: All the plots were in a perfectly weed free condition at the time of sowing. The first count represented the effect of pre-emergence and post-emergence applications and the first cultural operations on early weed

control while the second count was the net result of all the treatments at full flowering of the crop.

1. Effect of treatments: There was significant difference in the mean number of weeds in the differently treated plots at the first and second count. At the first count atrazine treatments and hoeing and weeding by hand hoe reduced the weed number from the other treatments including control, while at the second count atrazine treatments alone recorded a lesser number of weeds than the unweeded control. The results showed that atrazine applications effect season long control of weeds while the effect of hoeing and weeding was not long lasting.

Reduction in weed population by the use of atrazine and cultural methods have been reported by many early workers. Anderson (1964), Phillips (1965) and Lapchenkov (1966) reported similar results in sorghum. Burnside et al. (1964) reported weed yields decreased with tillage, narrow spacing and atrazine treatments and their combinations.

2. Tillage and weed population: Another interesting phenomenon observed on the weed count was a sudden increase of weed number in the hoed plot from 58.3 to 124.3 per quadrat from the first to the second count (Fig.8) while in the remaining treatments including control the weed population recorded considerable reduction. The increase in weed population in the hand hoed plot as a result of hoeing may be explained as due to bringing and exposure of weed seeds from the deeper layers to the surface where the conditions are more favourable for

emergence. Again the seedling weeds that were disturbed and left on the surface by hoeing would have re-established with subsequent rain or irrigation. The above explanation is in favour with that of Bunting (1963).

3. Weed competition: In the case of control, 2,4-D and ramrod treated plots the weed population recorded an appreciable reduction at the second count. This reduction in number was not accompanied by a corresponding reduction in the weight of weeds. Hence, the reduction in number without a reduction in the rate of growth cannot be attributed to any sort of treatment effect. This may be explained as a natural phenomenon resulting from competition among the weeds which resulted in the elimination of the weaker ones and survival and growth of the competent ones. The natural reduction was a characteristic of all treatment plots in which the treatments were not effective to control weeds (Fig.8). The same species viz., Trianthema portulacastrum dominated in both the counts. Hence the natural thinning took place within the same species. Harper (1960) stated that natural thinning which starts after germination resulted in thinning in which the proportion of seedlings killed increases with increasing density of seedlings. King (1966) said that in the seedling stage the most important problem of establishment in a dense stand of single species was competition. Charles Darwin and others opined that the severity of competition between plants belonging to the same species, because of similarity of their demands, was more than that between

individuals of two distinct species. In this case a competition resulting from a dense stand of Xiranthema may be accounted for the decline in weed population from the first to the second count.

4. Treatment comparisons: While comparing the effect of weed control treatments with the control, the difference was significant at the early stages of the crop growth while at later stages the difference was not significant. This might be due to the increase of weed population in the plots where cultural methods of weed control was adopted and on the natural reduction of population in the control plots. So, while averaging the treatments, the effect of atrazine treatments was masked by remaining treatments.

Comparing the efficiency of herbicides in reducing weed population the results were consistent from the early to the later stage of crop growth. On both the occasions the population in the atrazine plots was significantly low. Arle (1962) reported, effective season long control of Echinochloa crus-galli with atrazine at four pounds per acre. Anderson and Witworth (1967) observed 100 per cent control of grass and broad leaved weeds by pre-emergence and post-emergence application of atrazine in grain sorghum. Burnside and Robison (1967) found that among the herbicides tried on sorghum ramrod was the least effective in controlling weeds. The results showed that the times of application did not modify the herbicidal property of weedicides.

Between the cultural and chemical methods of weed control, on population basis there was no difference at the first count while at the second count the chemical methods were superior to cultural methods. The inference is that while the herbicides provide season long control, the effect of cultural methods were temporary. The failure of cultural methods to prolong the effect may be due to the regrowth of weeds as discussed earlier.

Among the cultural methods at the first count hoeing and weeding was superior to hand pulling while at the second count hoeing and weeding fell short of significance. The ineffectiveness of hand pulling to reduce weed population at the early stage might be due to the immediate regrowth of the broken parts and seedling weeds which escaped hand pulling owing to their smallness. Chancellor (1965) reported that the seeds of many weeds of arable crops germinated more freely in grounds cultivated at intervals of one month, three months or one year than in uncultivated ground. The majority were either stimulated or remained unaffected by cultivation.

Though the cultural methods have not reduced the population the weed growth was suppressed adequately as evidenced from the low weight of weeds present on both occasions (Fig.7) and the normal yields of the crop obtained from the cultural plots. Therefore, it might be concluded that the cultural methods were effective in suppressing weed competition considerably enough to raise a normal crop (Plate II).

iii) Weight of weeds: The dry weight yields from the differently treated plots showed significant differences in the first and second observations. The pattern of weed yields was similar for the two observations in that the high yields on the 45th day had similar yields on the 75th day and vice versa. This shows that the density of weed growth was almost uniform in the early and late stage of crop growth in the differently treated plots (Fig.7).

Weight of weeds was the least in the atrazine treated plots on both the occasions, this was followed by hand hoed and hand weeded plots in that order. The weight of weeds in the control plot was higher than that in the treated plots at the first and second count. This difference showed effectiveness of the various weed control methods in reducing weed growth. Burnside (1966) from a weed control experiment on sorghum with 11 treatments obtained significant reduction in dry weight yields of weeds in the treated plots. Bharadwaj and Verma (1961) in wheat and Bharadwaj and Verma (1963) in sugarcane observed significant reductions of weight of weeds.

Atrazine was significantly superior to 2,4-D and ramrod on both the occasions. Atrazine gave season long control of weeds and was most efficient among the herbicides (Plates VI and VII). Bovey and Burnside (1965) reported from an experiment in sorghum that atrazine was more effective than the other chemicals tried. Vengris (1967) concluded from a trial on field corn that ramrod alone or in combination with 2,4-D were not outstanding in broad leaved weed control.

Between times of application post-emergence application was most effective on both the occasions. The results indicated that for season long control of weeds post-emergence or a combination of pre and post-emergence application were the best. Albert (1961) reported that post-emergence application with 2,4-D gave excellent control of weeds. Robinson and Nelson (1964) from trials at four locations reported effectiveness of pre and post-emergence application of herbicides.

Though post-emergence applications provided season long control of weeds it had some disadvantage in that it allowed the weeds to compete with the crop in the early stage of crop growth. This early competition might be detrimental to the early vigour, stand and yield of the crop. Rademacher (1964) studying the effect of weed competition on oats at different stages of growth indicated the need for early application of herbicidal sprays to minimise yield loses.

The difference between the times of application was not significant in atrazine treated plots at the first and second observation whereas for 2,4-D the difference between times of application was significant at the second observation.

In the general comparison the cultural methods were superior to chemical methods in reducing weight of the weeds on both the occasions. The inefficiency of the chemical methods might be due to the ineffectiveness of 2,4-D and ramrod (Plates III, IV and V).

Both the cultural methods were equally effective in reducing weed weight at the first and second observation.

iv) Weed control: The results showed that atrazine treatments effected more than 94 per cent control of weeds on both the occasions of assessment while the cultural methods effected slightly above 50 per cent control at the early stage and 90 per cent control at the final assessment (Table 64). The crop performance was normal in the culturally weeded plots also.

Weed control by ramrod and 2,4-D was not sufficient enough to obtain normal crop performance. Any treatment of atrazine enabled season long control of weeds in sorghum. Morowitz (1963), Phillips and Ross (1965), Lapchenkov (1966) and Burnside (1966) from trials with different herbicides and time of applications on sorghum concluded that atrazine was the most efficient for weed control either as pre-emergence, post-emergence or in their combination.

Kukadi (1965) from the results of 10 years trials concluded that 2,4-D was less suitable for weed control in sorghum because of the short duration of its action.

Vengris (1967) from a weed control experiment on corn found that ramrod alone or in combination with 2,4-D were not outstanding in broad leaved weed control. Burnside and Robison (1967) from trials with different herbicides on sorghum at 27 locations, concluded that ramrod gave the least weed control.

v) Relationship of weed growth with sorghum yield:

Reduction of crop yields due to weed growth have been reported by Robinson (1949), Horowitz and Kletter (1963), Rowson (1964), Nieto (1965) and Bell and Nalowaja (1966). But much work has not been done to formulate a reliable estimate of weed growth on which the crop yield depended.

The results showed that the two estimates of weed growth viz., weed population and weed weight were negatively correlated with the yields of grain and straw. A high correlation coefficient between the weed weight and the grain yield revealed that among the two estimates of weed growth, weight of the weed was a better estimate than the population. Such correlations of yield on weed weight were reported by Lisa and Davis (1962) in wheat and Burnside and Wicks (1965) in sorghum. Burnside and Robison (1966) stated that weed yields were a less variable criterion for assessing weed control.

The linear regression equations (Table 66) showed that an increase in weed weight would cause a corresponding reduction in the yield of grain and straw (Figs. 9 and 10). Weed growth at the rate of 100 grams (dry weight) per 0.914 square metre (one square yard) 45 days after sowing caused a reduction of 358.6 kilograms grain and 1713.8 kilograms straw yield per hectare. Burnside et al. (1964) reported that every 50 pounds of weeds present in an acre lead to a loss of one bushel of sorghum grain per acre.

The significant correlation between weed weight and grain and straw yields at both the occasions of assessment indicated that the weed infestation in the field both at the early stage and at flowering were detrimental to the yield of sorghum.

D. ECONOMICS OF WEED CONTROL

The results showed that all the treatments except 2,4-D applied as pre and post-emergence and ramrod gave profits over control ranging from rupees 19 to 1055.50 per hectare (Fig.11). Among the various treatments, pre-emergence application of atrazine gave the maximum profit. Profits from pre-emergence application and post-emergence application of 2,4-D were not sizable.

Considering the efficiency of different weed control methods, from the quantity of extra grain produced per rupee invested in the different treatments, pre-emergence application of atrazine was the most efficient and economic treatment since the extra grain production per rupee was 15.648 kilograms. Hoeing and weeding by hand hoe yielded 11.933 kilograms per rupee.

It may be concluded from this study that the most economic and efficient method of weed control from the point of grain and straw yield was pre-emergence application of atrazine. Similar conclusions in favour of chemical or a combination of cultural and chemical methods of weed control have been reported by Mathur (1961) and Verma and Bharadwaj (1963).

E.RESIDUAL EFFECTS

i) Herbicide residue in crop: The absence of atrazine residue in sorghum plants at the time of harvest showed that there was no residue hazard in using atrazine for weed control in sorghum at the recommended rates of application.

Similar findings have been reported by some workers after investigating herbicide residue in crops. Colly and Harris (1966) studying metabolism of atrazine in maize reported that no unaltered atrazine was found in maize. Geigy (1966) detected no residue of simazine in fruits grown on treated orchards.

ii) Fertility of sorghum seed: The normal germination of the sorghum seeds collected from the various herbicide treated plots indicated that the herbicides had no adverse effect on fertility or germination of seeds and that the herbicides can be used safely on seed crops also.

Burnside and Wicks (1965) found no difference in germination of sorghum seeds collected from atrazine treated and cultivated plots. George et al. (1967) reported that atrazine application did not affect the seed set or germination percentage of sorghum grain.

iii) Germination of weed seeds: A non significant result on the germination of weed seeds showed that none of the herbicide treatments tried affected the viability or dormancy

of the seeds produced on the plants which survived the herbicide treatments.

The general low germination percentage (26 to 38) recorded in the weed seeds might be attributed to the inherent dormancy of Trianthema portulacastrum. Dale and Harrison (1966) and Dickerson et al. (1966) reported dormancy in newly matured weed seeds.

Aberg (1956) reported that when certain weeds were sprayed with hormone weed killers the seeds produced were non-dormant.

iv) Effect of herbicide application on subsequent crop: The normal emergence and growth of ragi and cotton sown in the soils treated with herbicides in the previous season indicated that there was no toxic level of herbicide residue present in the soil and that further cropping could be safely taken.

Lamba and Verma (1962) studying the residual effect of high rates of herbicides on the succeeding wheat sown eight to ten weeks after treatment reported no significant difference in any of the plant or yield characters. Sarpe et al. (1965) stated that wheat and peas could successfully follow atrazine treated maize provided the rate did not exceed three to four kilogram per hectare. Razlukina et al. (1966) reported that atrazine at 1.5 kilogram per hectare applied to maize had no toxic effect on the following years crop of carrots, beet roots, cabbage and tomatoes.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

The present investigation was undertaken to evaluate the efficiency of some of the herbicides for weed control in sorghum and to compare them with the standard cultural methods. The trial was conducted in a silty clay loam field under Coimbatore conditions on K.3 sorghum. The effect of weed growth on the crop and yield, necessity for intercultivation, the economics of weed control and the after effects of herbicide application were also studied.

The data on the various observations were analysed statistically and the following conclusions were drawn.

A. Weed control

1. Among the herbicides, atrazine was found to be the best for selective weed control in sorghum. Ramrod and 2,4-D were not effective and were inferior to the cultural methods.

2. Both the cultural methods viz., hoeing and weeding twice and hand pulling of weeds twice were equally efficient in controlling weeds.

3. Between atrazine applications and the cultural methods, atrazine applications provided season long control of weeds than the cultural methods.

4. Pre-emergence application of atrazine at the rate of 1.12 kilogram active ingredient per hectare was significantly superior to the standard cultural methods in increasing plant

height, leaf area of the plant, yield of straw per plant and per plot. In all other aspects it was comparable with the cultural methods.

5. All the times of application of atrazine were equally effective in controlling weeds and the differences between them were not significant except in plant establishment, where pre-emergence application was superior to the post-emergence application.

6. The interaction of herbicides with times of application was not significant except in leaf area of sorghum. Hence, for weed control, pre-emergence or post-emergence application of herbicides or a combination of the two was suitable.

7. Grain yield per plot in the atrazine treated and culturally controlled plots were on par and was superior to rest of the treatments.

8. Straw yield per plot in the atrazine pre-emergence treated plot was more than that in the cultural plots.

9. The most profitable and economic method of weed control for sorghum was pre-emergence application of atrazine.

B. Influence of weeds on the crop

1. Weed infestation of the field caused a reduction in the plant height, number and area of leaves, thickness of peduncle, length, breadth and weight of the earhead and the weight of grain per ear.

2. The thousand grain weight was not influenced by the weediness of the field.

3. Weed competition reduced the establishment of the crop.

4. Weight of the weed was found to be a reliable estimate of weed infestation than the number of weeds.

5. The grain and straw yield of the crop was negatively correlated with the weight of the weeds. The regression equations revealed a loss of 358.6 kilograms grain and 1713.8 kilograms straw per hectare for every 100 grams of dry weight of weeds present per 0.914 square metre (1 square yard) 45 days after sowing sorghum.

C. Effect of intercultivation

The intercultivation did not produce any beneficial effect on sorghum other than weed removal.

D. After effects of herbicide application

1. Pre-emergence application of herbicides at the doses tried had no adverse effect on the emergence of sorghum.

2. Crop injury to sorgaum was not caused by the post-emergence applications of atrazine and 2,4-D.

3. No residue of atrazine was detected in the sorghum plant by spectrophotometric analysis at the time of harvest.

4. Herbicide application did not affect the germination and growth of the subsequent cotton and ragi crops.

5. Herbicide application on the crop did not affect the germination of sorghum seed or dormancy of the weed seed Trianthema portulacastrum.

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* Originals not seen.

APPENDICES

Appendix I

Plant height

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	532.30		
Treatments	9	24900.16	2766.68	16.63**
Control Vs. Rest	1	5694.81	5694.81	34.20**
Cultural Vs. Chemical	1	81.01	81.01	<1.0
Hand pulling Vs. hoeing and weeding by hand hoe	1	164.32	164.32	<1.0
Between times of application	2	92.09	45.00	<1.0
Between herbicides	2	17422.93	8711.46	52.30**
Interaction of herbicides with times of application	2	313.66	156.83	<1.0
Error	18	2994.34	166.35	
Total	29	28426.80		

** Significant at P = 0.01 level

Appendix II

Number of leaves

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	4.169		
Treatments	9	7.041	0.7823	4.2090**
Control Vs. Rest	1	2.0280	2.028	10.914**
Cultural Vs. Chemical	1	0.1050	0.105	0.565
Hand pulling Vs. hoeing	1	0.2816	0.2816	1.51
Between times of application	2	0.082	0.041	0.220
Between herbicides	2	3.570	1.785	9.607**
Interaction of herbicides with times of application	2	0.070	0.035	0.188
Error	18	3.345	0.18583	
Total	29	14.555		

** Significant at P = 0.01 level

Appendix III

Leaf area

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	3060.41		
Treatments	9	143832.17	15981.35	41.47**
Control Vs. Rest	1	32272.37	32272.37	83.76**
Cultural Vs. Chemical	1	2754.59	2754.59	7.14*
Hand pulling Vs. hoeing and weeding	1	1277.50	1277.50	3.31
Between times of application	2	653.47	317.70	<1.0
Between herbicides	2	103516.67	51758.33	134.33**
Interaction of herbicides with times of application	2	2861.41	1430.71	3.71*
Error	18	6935	385.29	
Total	29	153827		

* Significant at P = 0.05 level

** Significant at P = 0.01 level

Appendix IV

Thickness of peduncle

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	0.00136		
Treatments	9	0.18726	0.0208	13.77**
Control Vs. Rest	1	0.06979	0.06979	46.22**
Cultural Vs. Chemical	1	0.008009	0.0080	5.30*
Hand pulling Vs. hoeing and weeding	1	0.000042	..	0.02
Between times of application	2	0.00152	0.00076	0.50
Between Herbicides	2	0.106546	0.0532	35.23**
Interaction of herbicides with times of application	2	0.000268	0.00013	<1.00
Error	18	0.02721	0.00151	
Total	29	0.21583		

* Significant at P = 0.05 level

** Significant at P = 0.01 level

Appendix V

Length of earhead

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	4.576		
Treatments	9	51.140	5.682	3.17*
Control Vs. Rest	1	16.089	16.089	8.982**
Cultural Vs. Chemical	1	1.207	1.207	< 1.0
Hand pulling Vs. hoeing and weeding	1	0.090	0.090	< 1.0
Between times of application	2	0.254	0.127	< 1.0
Between herbicides	2	33.186	16.593	9.26**
Interaction of herbicides with times of application	2	0.391	0.195	< 1.0
Error	18	32.241	1.791	
Total	29	87.957		

* Significant at P = 0.05 level

** Significant at P = 0.01 level

Appendix VI

Breadth of earhead

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	0.6373		
Treatments	9	11.5818	1.2868	7.17**
Control Vs. Rest	1	3.2604	3.2604	18.184**
Cultural Vs. Chemical	1	0.0737	0.0737	< 1.0
Hand pulling Vs. hoeing and weeding	1	0.0726	0.0726	< 1.0
Between times of application	2	0.0568	0.0289	< 1.0
Between herbicides	2	6.7322	3.3661	18.77**
Interaction of herbicides with times of application	2	0.9325	0.4662	2.600
Error	18	3.2285	0.1793	
Total	29	15.4476		

** Significant at P = 0.01 level

Appendix VII

Weight of earhead

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	59.461		
Treatments	9	6448.303	716.478	15.959**
Control Vs. Rest	1	1888.662	1888.662	42.07**
Cultural Vs. Chemical	1	355.155	355.155	7.91*
Hand pulling Vs. hoeing and weeding	1	2.940	2.940	<1.0
Between times of application	2	40.877	20.432	0.45
Between herbicides	2	4041.686	2020.843	45.01**
Interaction of herbicides with times of application	2	71.744	35.872	0.79
Error	18	808.086	44.893	
Total	29	7315.850		

* Significant at P = 0.05 level

** Significant at P = 0.01 level

Appendix VIII

Weight of grain per ear

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	40.673		
Treatments	9	5718.025	635.336	15.05**
Control Vs. Rest	1	1585.102	1585.102	40.03**
Cultural Vs. Chemical	1	348.403	348.403	8.79**
Hand pulling Vs. Hoeing and weeding	1	6.615	6.615	< 1.0
Between times of application	2	22.655	11.327	< 1.0
Between herbicides	2	3620.626	1810.380	45.72**
Interaction of herbicides with times of application	2	91.197	45.59	1.15
Error	18	712.621	39.573	
Total	29	6471.319		

** Significant at P = 0.01 level

Appendix IX

Thousand grain weight

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	3.1157		
Treatment	9	37.1661	4.1295	2.132
Error	18	34.8554	1.9364	
Total	29	75.1322		

Appendix X

Yield of straw per plant

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	693.005		
Treatments	9	18156.965	2017.44	9.47**
Control Vs. Rest	1	3434.700	3434.700	16.12**
Cultural Vs. Chemical	1	80.981	80.981	1.0
Hand pulling Vs. Hoeing and weeding	1	185.259	185.259	1.0
Beteen times of application	2	231.254	115.627	1.0
Between herbicides	2	12637.987	6318.990	29.66**
Interaction of herbicides with times of application	2	89.714	44.850	1.0
Error	18	3834.220	213.010	
Total	29	22684.190		

** Significant at P = 0.01 level

Appendix XI

Crop emergence

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	26.168		
Treatments	9	125.063	13.895	1.24
Error	18	200.355	11.130	
Total	29	351.583		

Appendix XII

Plant establishment

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	0.817		
Treatments	9	102.540	11.393	28.55**
Control Vs. Rest	1	12.245	12.245	30.68**
Cultural Vs. Chemical	1	11.177	11.177	28.01**
Hand pulling Vs. Hoeing and weeding	1	1.500	1.500	3.75
Between times of application	2	0.146	0.733	1.0
Between herbicides	2	73.507	36.753	92.11**
Interaction of herbicides with times of application	2	1.777	0.888	2.22
Error	18	7.183	0.399	
Total	29	110.540		

** Significant at P = 0.01 level

Appendix XIII

Grain yield per plot

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	14.00		
Treatments	9	630.0481	70.0053	12.07**
Control Vs. Rest	1	76.8053	76.8053	13.24**
Cultural Vs. Chemical	1	140.6416	140.6416	24.25**
Hand pulling Vs. Hoeing and weeding	1	9.0282	9.0282	1.55
Between times of application	2	0.4444	0.2222	< 1.0
Between herbicides	2	386.1916	193.0958	33.30**
Interaction of herbicides with times of application	2	7.5765	3.7892	< 1.0
Error	18	104.3715	5.7984	
Total	29	784.4196		

** Significant at P = 0.01 level

Appendix XIV

Straw yield per plot

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	201.95		
Treatments	9	13305.18	1478.35	25.64**
Control Vs. Rest	1	1659.60	1659.60	28.79**
Cultural Vs. Chemical	1	962.47	962.47	16.69**
Hand pulling Vs. Hoeing and weeding	1	9.80	9.80	<1.0
Between times of application	2	30.05	15.02	<1.0
Between herbicides	2	10455.77	5227.88	90.69**
Interaction of herbicides with times of application	2	34.58	17.29	<1.0
Error	18	1037.61	57.645	
Total	29	14544.47		

** Significant at P = 0.01 level

Appendix XV

Weed population on 45th day after sowing

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	3837.80		
Treatments	9	125058.96	13895.44	16.03**
Control Vs. Rest	1	14097.78	14097.78	16.27**
Cultural Vs. Chemical	1	4.47	4.47	<1.0
Hand pulling Vs. Hoeing and weeding by hand hoe	1	9841.50	9841.50	11.35**
Between times of application	2	1439.07	719.53	0.83
Between herbicides	2	99924.34	49962.17	57.67**
Interaction of herbicides with times of application	2	690.77	345.38	<1.0
Error	18	15594.29	866.34	
Total	29	1/44491.00		

** Significant at P = 0.01 level

Appendix XVI

Weed population on 75th day after sowing

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	1070.06		
Treatments	9	38811.46	4312.38	8.32**
Control Vs. Rest	1	2161.83	2161.83	4.17
Cultural Vs. Chemical	1	18746.67	18746.67	36.19**
Hand pulling Vs. Hoeing and weeding by hand hoe	1	600.00	600.00	1.15
Between times of application	2	2181.23	1090.61	2.10
Between herbicides	2	16436.06	8218.03	15.86**
Interaction of herbicides with times of application	2	138.77	69.38	<1.0
Error	18	9321.93	517.88	
Total	29	49203.46		

** Significant at P = 0.01 level

Appendix XVII

Weight of weeds on 45th day after sowing

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	9655.30		
Treatments	9	932745.00	103638.33	21.85**
Control Vs. Rest	1	122752.03	122752.03	25.88**
Cultural Vs. Chemical	1	27720.02	27720.02	5.84*
Hand pulling Vs. Hoeing and weeding	1	18704.16	18704.16	3.94
Between times of application	2	50371.04	25185.51	5.31**
Between herbicides	2	741720.01	370860.00	78.22**
Interaction of herbicides with times of application	2	9822.00	4911.00	1.03
Error	18	85351.70	4741.76	
Total	29	1027752.00		

* Significant at P = 0.05 level

** Significant at P = 0.01 level

Appendix XVIII

Weight of weeds on 75th day after sowing

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Blocks	2	1708.7		
Treatments	9	1091923.2	121324.0	33.45**
Control Vs. Rest	1	180859 .7	180895.7	49.87**
Cultural Vs. Chemical	1	187779.3	187779.3	51.78**
Hand pulling Vs. Hoeing and weeding	1	541.5	541.5	<1.0
Between times of application	2	40832.6	20416.3	5.63*
Between herbicides	2	703630.0	351815.0	96.91**
Interaction of herbicides with times of application	2	7516.5	3758.2	1.03
Error	18	65269.3	3626.12	
Total	29	1158901.2		

* Significant at P = 0.05 level

** Significant at P = 0.01 level

Appendix XIX

Germination of sorrhur seeds

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Treatments	7	883.96	126.28	2.244
Error	16	899.99	56.24	
Total	23	1783.95		

Appendix XX

Germination of weed seeds

Analysis of variance

Source	D.F.	S.S.	M.S.	F
Treatments	7	363.29	51.89	0.61
Error	16	1354.66	84.66	
Total	23	1717.95		

ILLUSTRATIONS

FIG.1

N

PLAN OF FIELD LAY OUT

SCALE 1CM = 4.572 METRE

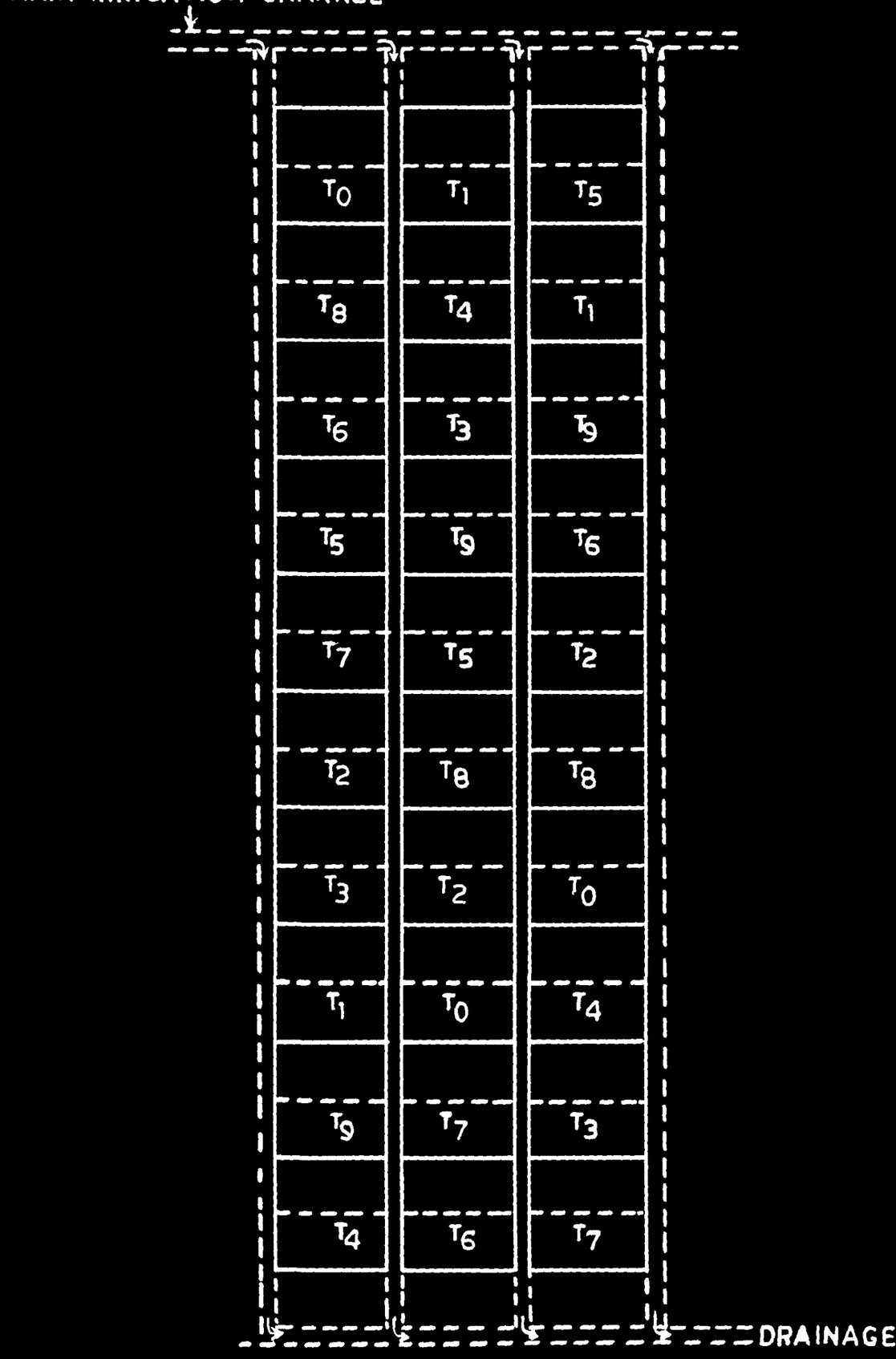


FIG.2.

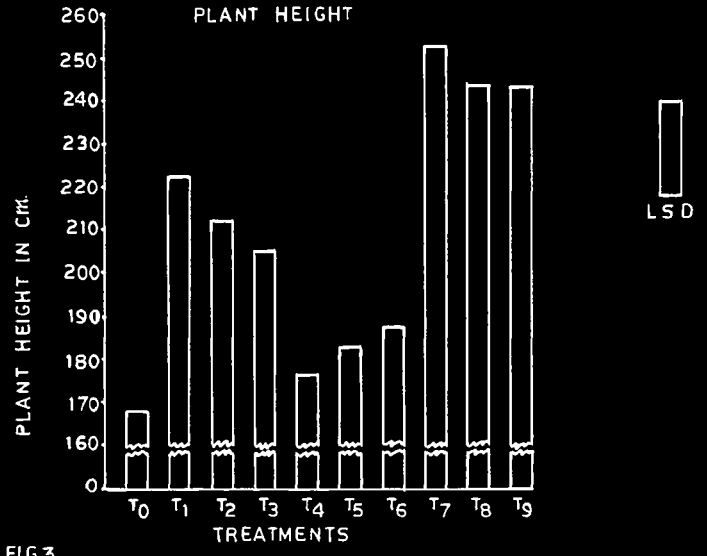

PLANT HEIGHT
PLANT HEIGHT IN CM.
260
250
240
230
220
210
200
190
180
170
160
0
T0 T1 T2 T3 T4 T5 T6 T7 T8 T9
TREATMENTS
LSD

FIG.3

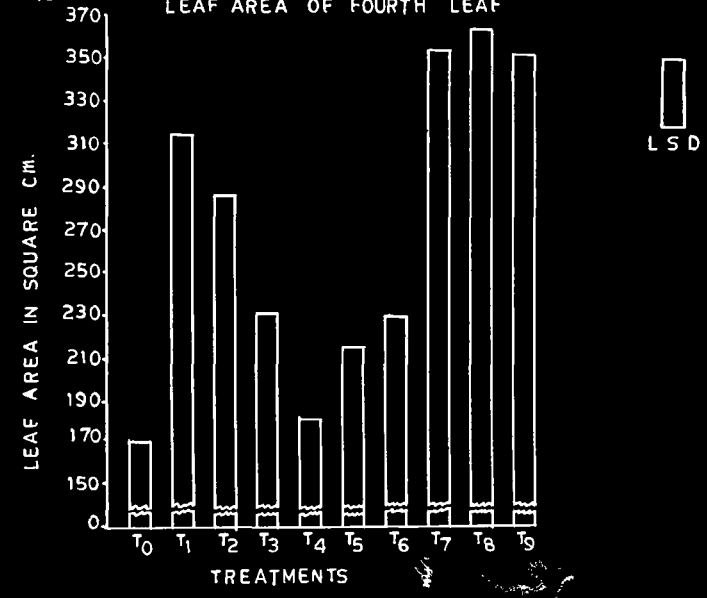

LEAF AREA OF FOURTH LEAF
LEAF AREA IN SQUARE CM.
370
350
330
310
290
270
250
230
210
190
170
150
0
T0 T1 T2 T3 T4 T5 T6 T7 T8 T9
TREATMENTS
LSD

FIG.4. LENGTH OF EAR

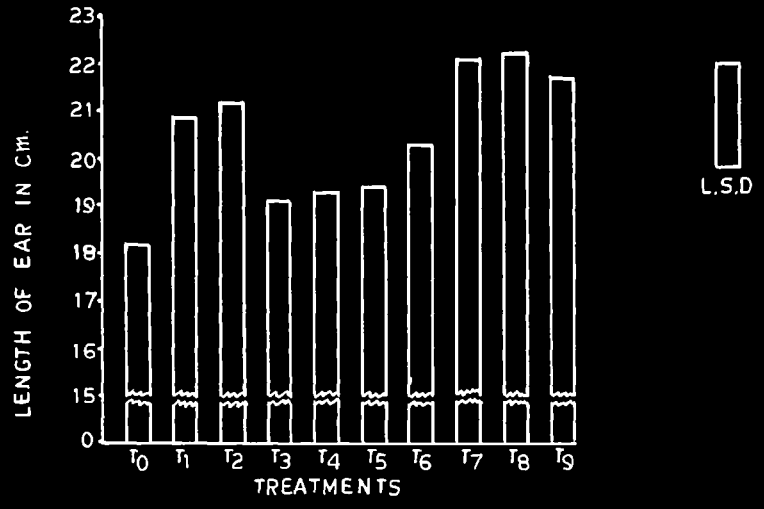


FIG.5. WEIGHT OF GRAIN PER EAR

FIG.6

YIELD OF GRAIN AND STRAW PER PLOT

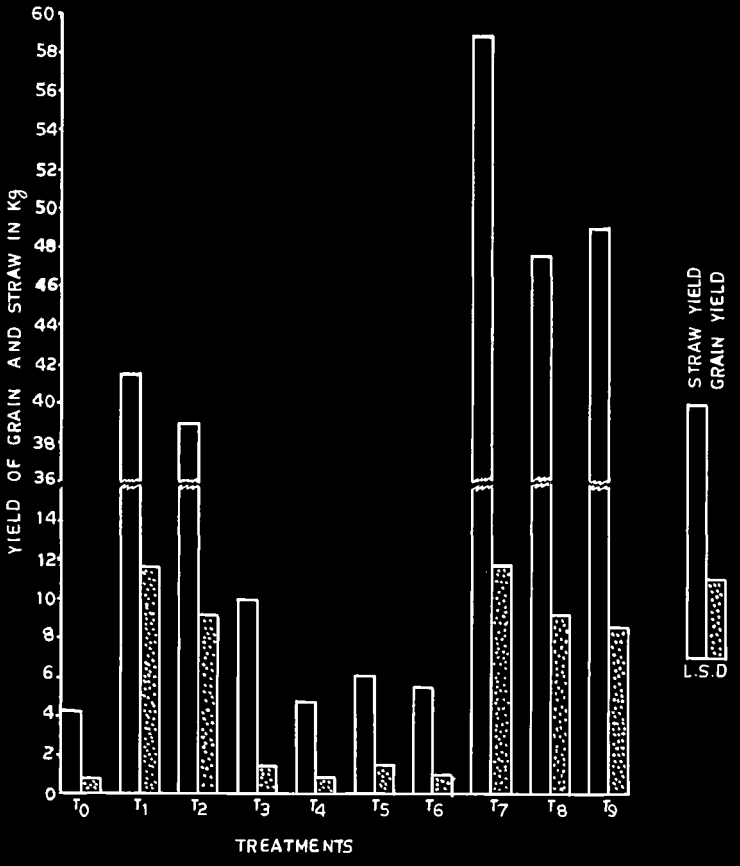


FIG.7

WEED WEIGHT PER 0.914 SQUARE METRE

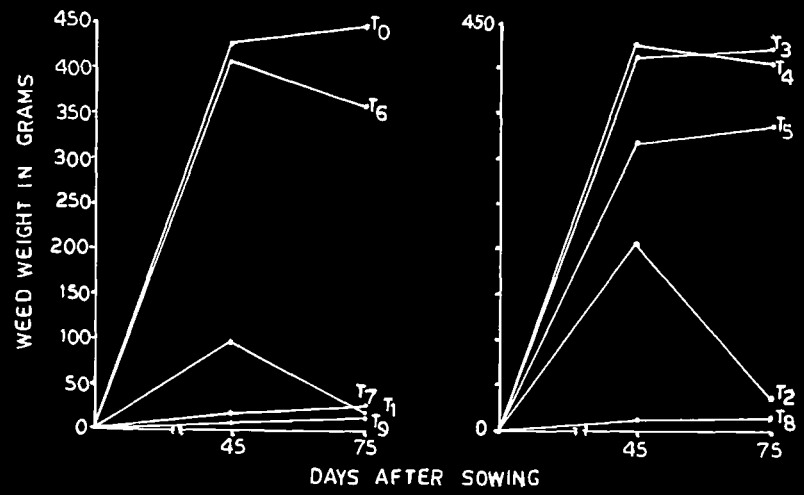


FIG.8. WEED COUNT PER 0.914 SQUARE METRE

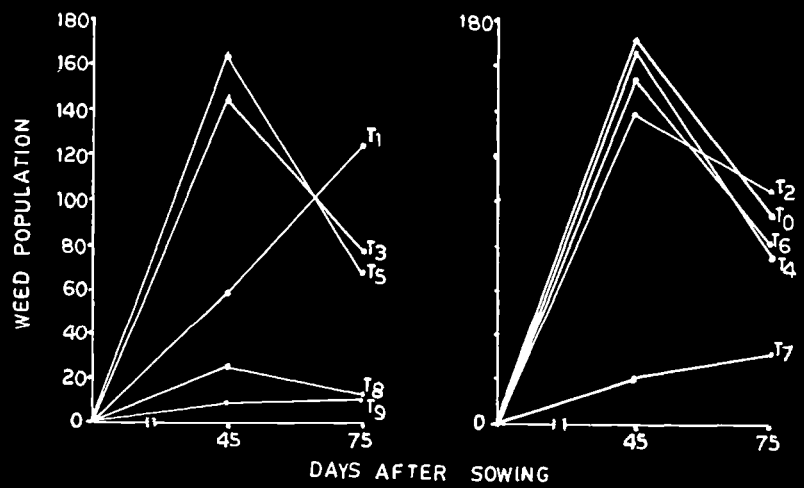


FIG.9.

LINEAR REGRESSION OF YIELD OF GRAIN(y) ON WEED WEIGHT(x)

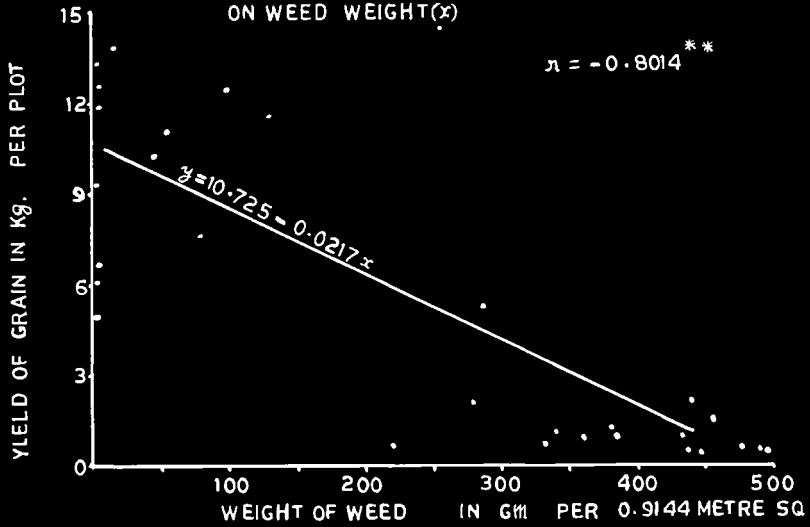


FIG.10.

LINEAR REGRESSION OF YIELD OF STRAW(y) ON WEED WEIGHT(x)

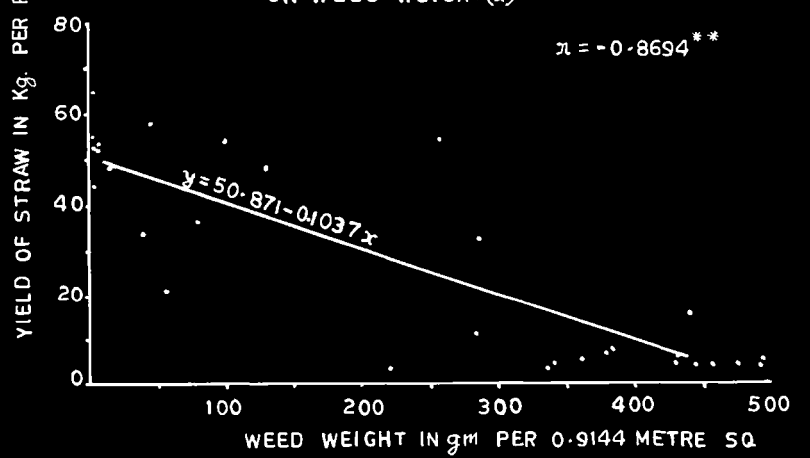


FIG.11 NET PROFIT PER HECTARE IN Rs.

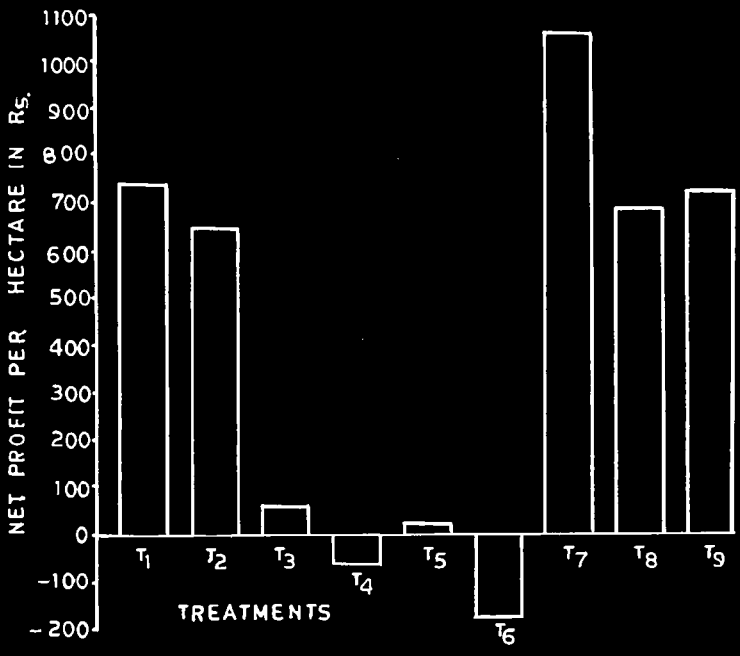


FIG.12.

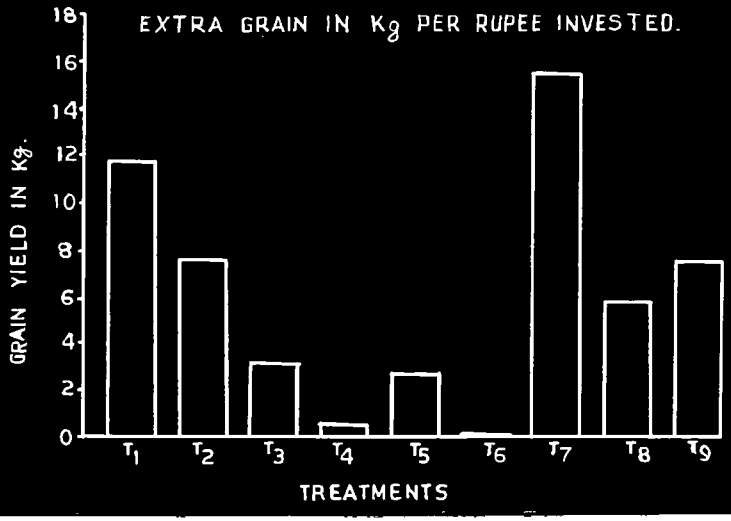
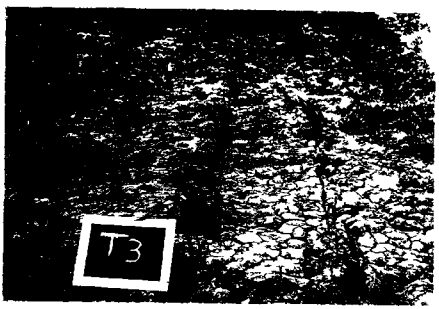


PLATE I

EFFECT OF PRELEMERGENCE APPLICATION OF HERBICIDES



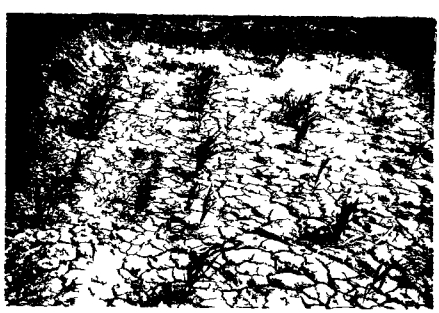


PLATE II

WEED GROWTH IN CULTURAL PLOTS

PLATE III

WEED GROWTH IN 2, 4-D TREATED PLOTS ON 45TH DAY

PLATE IV

WEED GROWTH IN 2, 4-D TREATED PLOTS AT HARVEST

PLATE V

WEED GROWTH IN CONTROL AND RAMROD TREATED PLOTS

PLATE VI

EFFECT OF ATRAZINE APPLICATIONS ON 45TH DAY

PLATE VII

EFFECT OF ATRAZINE APPLICATIONS AT HARVEST

PLATE VIII

GROWTH OF SORGHUM IN DIFFERENT TREATMENTS AT HARVEST