

**PHYSIOLOGICAL STUDIES ON WEED CONTROL
EFFICIENCY IN ONION (*Allium cepa* L.)**

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COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES

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**PHYSIOLOGICAL STUDIES ON WEED CONTROL
EFFICIENCY IN ONION (*Allium cepa* L.)**

Thesis Submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfilment of the requirements for the
Degree of

Master of Science (Agriculture)

in

CROP PHYSIOLOGY

By

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CERTIFICATE

This is to certify that the thesis entitled "**PHYSIOLOGICAL STUDIES ON WEED CONTROL EFFICIENCY IN ONION (*Allium cepa* L.)**" submitted by **S. N. PATIL** for the degree of **Master of Science (Agriculture)** in **Crop Physiology**, to the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any other degree, diploma, associateship, fellowship or other similar titles.

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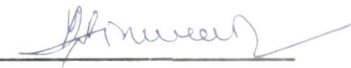
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2024

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DHARWAD

NOVEMBER, 1999


(S. N. PATIL)

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INTRODUCTION

I. INTRODUCTION

Onion (*Allium cepa* L.) is one of the important commercial vegetable crop of India on account of its high yielding ability and storage suitability. It is an ancient crop having been utilized in medicines and rituals, besides being consumed as food in Egypt (3200 BC) and in India (600 BC). The primary centre of origin of onion is Central Asia and Mediterranean region is the secondary centre of origin (McCollum, 1976).

Onion is being cultivated in wide geographical and ecological zones which lead to the selection of various types and this has increased the diversity of the crop. Onion bulb is rich in minerals, especially calcium and phosphorus, besides having fairly good quantities of carbohydrates, proteins and vitamin C. The pungency in onion is due to the volatile compound known as allylpropyl disulphide and this pungency has contributed for its popularity and diversified use.

The onions are indispensable part of many preparations as flavouring agent. The green leaves and immature as well as mature bulbs are eaten raw or in cooked form. Dehydrated products of onions are in great demand worldwide and are used for flavoring canned meat products and other food preparations.

It is commercially cultivated in about one hundred countries of the world. About 38.15 million tons of onion is produced annually all over the world from an area of about 2.29 million hectares. The world average yield of onion bulbs is around 16.65 tonnes per hectare (Anon., 1997).

India's contribution to the world production is 13 per cent and ranks second, the first being China. The total area under this crop is 2.95 lakh hectares with an annual production of 34.00 lakh tonnes (Sumit, 1998). India

inspite of being the major onion producing country, has very low productivity (11 t/ha).

Karnataka is the leading state in the cultivation of onion next to Maharashtra and Gujarat. In Karnataka, Dharwad, Chitradurga, Bijapur, Bellary, Gulbarga and Chikkamangalore are the major districts, occupying an area of 0.602 lakh ha with a production of 4.45 lakh tonnes. However, the productivity is very low (7.0 t/ha) as compared to the National productivity (Peter, 1996).

Crop-weed competition is severe in both irrigated and rainfed onion. As with many other crops, production of onion is greatly reduced by unrestricted weed growth. Though onion is a hardy crop, it is a very poor competitor with weeds on account of its inherent characteristic traits such as short stature, non-branching habit, sparse foliage, shallow root system and extremely slow growth in the initial stages, which could cause quick growth of weeds. Moreover, use of liberal doses of fertilizers and more frequent irrigation creates favourable conditions for weed growth (Rajendra Singh *et al.*, 1986).

It is an established fact that weeds compete with crop plants for space, nutrients, moisture and light, thereby reducing the growth and yield. In onion, weeds emerge with the transplanting of crop seedlings and grow along with them. This causes severe competition between the crop and weeds (Bhan *et al.*, 1976). If the weeds are present throughout the crop growth period, there may be complete loss of marketable yield.

In competition with weeds, the photosynthetic capacity and consequently bulb size of onion plant is greatly reduced. The loss of yield is mainly due to decrease in bulb size. Competitive ability of the crop at a critical

stage is low and the presence of weeds will reduce the yield considerably. The reduction in bulb yield varies to the extent of 48 to 85 per cent depending upon the duration and intensity of the crop-weed competition (Bhalla, 1978). Because of slow initial growth of onion seedlings, there is a need for weed free maintenance during early stages of crop growth. The weed flora which emerge late do not have any significant effect on the growth and yield of onion. Hence, there is an urgent need to develop effective methods of weed control in onion (Bhan *et al.*, 1976).

Periodical manual removal of weeds is the only conventional practice and it accomplishes the job effectively after establishment of weeds but it is tedious, expensive and time consuming. Moreover, it is difficult to carry out the field operation using implements due to narrow spacing between the rows and shallow root system of the crop. Scarcity of labour and concurrent rise in the cost of hand weeding due to intensification and diversification of other cropping systems, timely removal of weeds by labour is difficult and expensive (Hamdoun and Babiker, 1978; Babiker, 1979).

Chemical weed control is a miracle of the technological development (Ashton and Crafts, 1973). Various herbicides have been used all over the world and have shown good promise in a variety of crops. A good number of herbicides is now available in the market which can be used effectively and economically (Bhalla, 1978).

Herbicides can be effectively used for early season weed control in onion. The effectiveness of a herbicide is determined by soil type, organic matter, weather conditions, soil moisture etc.

Therefore, it is essential to screen several newly released herbicides and to fix optimum doses under particular agro-climatic conditions for effective

control of weeds in onion. With this background, the present investigation was carried out with the following objectives.

1. To know the effect of different herbicides on morpho-physiological traits in direct seeded onion.
2. To know the effect of different herbicides on yield and yield components in direct seeded onion.
3. To know the effect of herbicides on weed control efficiency in direct seeded onion.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Weed infestation is one of the limiting factors in successful crop production. Any plant competing with cultivated plants or that in some other way interfere with man's legitimate activities is considered to be a weed. Weeds are often referred to as unwanted, prolific, persistent, competitive and harmful to the total environment. Weeds are a great menace and a reduction in crop yield has a direct correlation with weed competition. An attempt has been made to collect the available literature on various aspects of weed control in onion are presented.

2.1 WEED FLORA

The degree of damage caused by weeds is related to the type, species and density of weeds growing in a crop community. Weed species are known to vary with the season and type of cultivation. Persistence of weeds in a location is largely influenced by climatic, edaphic (soil) and biotic factors which affect their occurrence, abundance, range and distribution.

Bhan *et al.* (1976) reported that onion crop grown for vegetable, faces severe infestation of broad leaf annual weed *Chenopodium album* L. which emerges with the transplanting of seedlings during rabi season.

Gajraj Singh *et al.* (1982) reported that the main weed species prevalent in the onion crop on sandy loam soils were *Cyperus rotundus*, *Cynodon dactylon*, *Pennisetum* spp., *Echinochloa crusgalli* sp., *Chenopodium album*, *Ecalipta alba*, *Amaranthus viridis*, *Euphorbia* spp., *Trianthema manogyna* and *Femeria Parviflora*. While, Patel *et al.* (1983) observed that the predominant weed flora under the agroclimatic condition of South Gujarat in onion fields were *Panicum colonum* L., *Brachiaria erviformis* L., *Echinochloa colonum* L.,

Cyperus rotundus L., (among monocots) and *Portulaca oleracea* L., *Trianthema portulacastrum* L., *Eclipta alba* Hassk, *Physalis minima* L., and *Amaranthus viridis* L., (among dicots).

Govindra Singh *et al.* (1985) found that the predominant weeds on sandy loam soils at Pantanagar were *Echinochloa colonum* L., Link (32.2%), *Chinopodium album* L. (12.8%), *Polypogon monspeliensis* (L.) Desf. (16.1%), *Amaranthus viridis* L. (9.1%) and *Melilotus* spp. (6.4%) .

Mishra *et al.* (1986) recorded the weed species in onion field trial at Pusa (Bihar) on sandy loam soil in the descending order of infestation intensity were *Cyperus rotundus* L., *Cynodon dactylon* L., *Scirps moritimus* L., *Asphodelus tenuifolius* L., *Trianthema Portulacastrum* L., *Melilotus indica* L., *Anagalis arvensis* L., *Canabis sativa* L., *Acalypha indica* L., *Euphorbia microphyla* L., *Vicia sativa* L., *Convolvulus arvensis* L., *Amaranthus viridis* L., *Cirsium arvensis* L., and *Launea pinnatifida* L.

Phogat *et al.* (1989) reported that *Cyperus rotundus*, *Dacteloctenium aegypticum*, *Echinocloa colonum* and *Trianthema portulacastrum* were found to be the predominant weed species in the onion crop at Karnal. Pandey *et al.* (1990) observed that the dominant weed flora in onion during *Kharif*, were *Chloris barbata*, *Cynadon dactylon*, *Dacteloctenium aegypticum*, *Digitaria adscendeus*; and *Echinocloa crusgalli* among grasses; and *Cyperus rotundus* among sedges; and *Sida carpinifolia*, *Parthenium hysterophorus*, *Ageratum conyzoides*, *Melilotus* spp., *Amaranthus viridis*, *Vicia sativa*, *Anagallis arvensis* and *Euphorbia geniculata* among broad leaved weeds.

The dominant weed flora on sandy loam soils of Bangalore were *Digitaria marginata* Link., *Dacteloctenium aegypticum* Picht., *Cynodon dactylon* Pers.,

Echinochloa colonum (L.) Link., *Eragrostis pilosa* Beauv., and *Eragrostis ciliensis* Wallink., among monocots and *Acanthospermum hispidum* Dc., *Amaranthus viridis* L., *Euphorbia hirta* L., *Ageratum conyzoides* L., *Portulaca quadrifida* L., *Bidens pilosa* L., *Euphorbia geniculata* Qrt., *Phyllanthus niruri* DC., *Parthenium hysterophorus* L., among dicots (Hanumanthraju, 1992).

Singh *et al.* (1992) observed that the dominant weed species were *Cyperus rotundus* L., *Cynodon dactylon* L., among narrow leaved weeds; *Trianthema portulacastrum* L., *Melilotus indica* L., *Asphodelus tenuifolium* L., *Anagallis arvensis* L., *Cannabis* L., and *Launa pinnetifida* among broad leaved weeds in onion at Pusa (Bihar).

The weed flora of experimental field at Varnasi were found to be *Eragrostis tenella* (Raem) Scjitt, *Cyperus rotundus* L., *Trianthema portulacastrum* L., *Echinochloa crus-galli* (L.) Beauv., *Ageratum conyzoides* L., *Portulaca Oleracea* L., *Portulaca quadrifida* L., *Cleome viscosa* L., *Euphorbia hirta* L., and *Desmodium trifolium* L., during *kharif* seasons (Singh and Singh, 1994).

Shah and Patel (1995) noticed that during *rabi* season, *Echinochloa crus-galli* (L.) Beauv., and *Echinochloa colonum* Link., among monocots; *Portulaca Oleracea* L., *Digeria arvensis* L., *Amaranthus viridis* L., among dicots were predominant weeds in onion field.

Nadagouda (1995) observed that the weed flora in onion field at Belawatagi (Dharwad) were *Cyperus rotundus*, *Cynodon dactylon*, *Setaria glauca*, *Pennisetum* Spp., *Echinochloa crus-galli*, *Digitaria sanguinalis*, *Commelina bengalensis*, *Cynotis cristata* among monocots, *Parthenium hysterophorus*, *Phyllanthus niruri*, *Convolvulus arvensis*, *Hibiscus ponduriformis*, *Chenopodium*

album, *Trianthema monogyna*, *Eclipta alba*, *Amaranthus viridis*, *Euphorbia* Spp., *Portulaca oleracea*, *Lactuca ranchinata*, *Lagasca mollis*, *Phyllanthus maderapatensis*. While, Singh *et al.* (1996) observed that the dominant weed flora of the experimental plot of onion at Nauri (Solan) were *Cyperus rotundus*, *Medicago denticulata*, *Coronpus didymus*, *Poa annua*, *Rumex acetosella*, *Cynadon dactylon* and *Ageratum conyzoides*.

2.1 CROP-WEED COMPETITION

Crop and weeds compete for nutrients, water, space and light. Competition begins when annual weeds remain in crops for longer than a certain time after the crop emergence. Such crop weed competition in onion results in serious bulb yield loss, mainly because of reduction in bulb size (Bleasdale, 1959; Hewson and Roberts, 1971).

In the development of a crop, there is a critical stage at which the competitive ability of the crop is low and the presence of weeds will reduce yield considerably. The reduction in bulb yield varied from 48 to 85 per cent depending upon the duration of crop-weed competition and the intensity of weeds (Bhalla, 1978). The crop growth, crop density, stage of the crop, besides existing weed density and growth stage decides the ability of the crop to compete with the weeds for environmental factors.

The yield reduction to the extent of 78.1 per cent in seeded onion and 53.0 per cent in transplanted onion has been noticed by Singh *et al.* (1990). Similarly, Singh *et al.* (1996) noticed the yield reduction to the tune of 86.05 per cent.

Critical period is the shortest time span in the ontogeny of crop growth when weeding results in highest economic returns. The presence of weeds in crop interfere with crop growth at any time or stage. It is true to the some extent that it is neither economical nor feasible to maintain a completely weed free condition throughout the growth period of the crop. Therefore, it is a must to identify the stage of crop when the damage is maximum. This damage is more pronounced in crops which have slow growth habit, shallow rooted and short statured particularly during the early stages of growth. Hence, the elimination of competition by the weeds during this period would help the crop plants to grow better and consequently yield better. Therefore, it is imperative that the critical period of crop-weed competition need to be determined so as to obtain the maximum benefits from effective and efficient weed management practices.

Deuber and Forster (1972) reported that the effect of weed competition on quality and yield of onion cv. Monte Alegre was less in the first six weeks after transplanting than it was from the seventh week until the harvest.

The competition between weeds and onions was found to occur mainly between 21 and 84 days after transplanting (Compegia 1973). Weeds left upto 21 days after transplanting did not affect yields and weed free upto 84 days gave only slightly reduced yields compared with the control kept weed-free throughout crop period. Further, Lucas and Gauntes (1973) reported that first seven weeks after transplanting of onion is the most critical period of crop-weed competition. Therefore, the field should be kept weed-free for at least seven weeks after transplanting to get maximum onion yields.

Casamayor *et al.* (1974) observed that period at which weed competition most adversely affects the onion is 30 to 40 DAT under cuban conditions. Absence of weeds throughout the first six weeks from transplanting is essential for good yields.

Bhan *et al.* (1976) reported that onion crop faces weed competition during the early stages of crop growth and keeping fields weed-free for initial 45 days is sufficient to avoid the loss in bulb yield caused due to the presence of weeds. Roberts (1976) concluded that there was no adverse effect on onion bulb yield provided the weed-free condition for about 5 weeks after 50 per cent crop emergence and the plots were subsequently kept clean.

Bhalla (1978) reported that if the crop is kept clean for the first 6-8 weeks or more after 50 per cent emergence, weeds that developed subsequently do not affect the yield. The critical period was found to be the emergence of 3rd true leaf. While, Thomas and Wright (1984) reported that the crop is susceptible to weed competition between second and tenth week after 50 per cent emergence.

Babikar *et al.* (1987) noticed that unrestricted growth reduced the crop yield by 98 per cent and onion was most sensitive to weed competition between the second and sixth week after crop emergence. While, Singh and Singh (1994) noticed at Varanasi on sandy loam soils that the critical period of crop-weed competition existed during the first 15 to 60 days after transplanting.

2.4 EFFECT OF WEEDS ON CROP GROWTH AND YIELD

Many workers have emphasized that the effect of weeds on growth and yield components ultimately decide the yield. The reduction may occur as a

result of competition between the crop and weed for nutrients, space, light and water (Klingaman, 1961). Weeds thrive better than the crop plants when left uncontrolled and they can grow taller than the crop plants and suppress the growth to a considerable extent.

Bhan *et al.* (1976) observed that onion crop faces weed competition during early stages of crop growth. While, Roberts (1976) reported that the main reason for the serious nature of weed competition in onion appears to be the very slow germination and early growth. By the time onion enters the exponential phase, the weed weight per unit area has been estimated to be twenty times that of the crop.

Gajraj Singh *et al.* (1982) studied that in unweeded plot of onion crop, there was severe competition of weeds and which produced poor sized bulbs resulting in lower yield. While, Mishra *et al.* (1986) noticed that unrestricted weed growth reduced the crop yield by 98 per cent.

Manjunath and Panchal (1989) found that the presence of weeds affected the plant height, leaf area index (LAI), leaf area duration (LAD), net assimilation rate (NAR) and crop growth rate (CGR) in onion. Weeds also affected the yield components *viz.*, bulb diameter, bulb dry weight and harvest index and reduced the bulb yield drastically.

Unweeded plots were observed to record reduced plant height, number of leaves, which in turn reduced the bulb diameter and bulb yield due to increased weed competition (Singh and Singh, 1994).

2.5 METHOD OF WEED CONTROL

Various methods used to manage the weeds have their own merits and demerits. The final selection of any method will largely depend on its effectiveness and economics.

Where labour is scarce and expensive, the use of herbicides hold a good promise for timely, effective and efficient weed control. Since most weeds emerge either before or along with the crop, the use of pre-sowing incorporation and pre-emergence herbicides is a better management practice. The choice of herbicide for a particular situation will depend upon the climate, soil type, prevalent weed species, crop cultivar and method of propagation and management.

The reviews pertaining to chemical method of weed control are presented here.

2.5.1 Alachlor

Thakral *et al* (1981) stated that alachlor, propanil and prometryne weedicides controlled broad leaved weeds very effectively when sprayed a week after planting although they appeared in later stages, but had no adverse effect on the seed yield. The results of field experiments on weed management practices revealed that both levels of alachlor (1.5 and 2.0 kg/ha) and lower level of herbicide + weeding at 40 DAT were quite effective in checking the weed growth, leading to significant increase in bulb diameter and yield as compared to unweeded control (Patel *et al.*, 1983).

The application of alachlor at 2.0 kg/ha resulted in significant increase in bulb yield. But oxadiazon at 1.0 kg/ha was more effective than other herbicides applied (Govindra Singh *et al.*, 1985).

Rajendra Singh *et al.* (1986) conducted field experiments on comparative performance of herbicides. The results revealed that pre-planting application of alachlor at 1.25 kg a.i./ha and nitrofen at 1.0 kg a.i./ha reduced the weed population and growth particularly nutsedge which formed the major weed flora of the onion plots.

Mishra and Sharma (1990) reported that application of alachlor at 2.0 kg/ha resulted in significantly higher yield next to oxadiazon 1.0 kg/ha and the treatments with hand weeding were not economical. While, Verma and Singh (1996) reported that the application of alachlor @ 1.5 and 2.0 kg/ha gave higher yields next to pendimethalin @ 1.0 and 1.5 kg/ha, but was on par with metolachlor (1.0 and 1.5 kg/ha).

2.5.2 Oxfluorfen

Putnam and Riley (1980) reported that the application of oxyfluorfen at 0.28 and 0.56 kg/ha to onions at 2 to 3 leaf stage gave excellent control of *Portulaca oleracea* and *Amaranthus retroflexus* without reducing onion yields compared with hand weeding during 1979, whereas during 1980, oxyfluorfen E.C. at 0.14 kg/ha once or twice or three times controlled *P.oleracea*, *Stellaris media* and *Polygonum persicaria*. In general, E.C. formulations were effective than w.p. formulations against weeds.

Application of oxyfluorfen @ 0.1 - 1.0 kg/acre in onion at two to 14 leaf stage, resulted in the control of annual weeds at 0.25 kg/ha, while the older weeds were controlled or heavily damaged at higher concentration. These weeds were *Malva nicacensis*, *Convolvulus arvensis*, *Solanum luteum*, *Sinapis arvensis*, *Notobosis syriaca*, *Xanthium Sp.*, *Ecabaliu elatericum*, *Chrozophora tinetoria*, *Portulaca oleracea*, *Foeniculum vulgare*, *Dacus bicolor*, *Avena sterilis*

and *Phalaris* Sp.(Abada *et al.*, 1982). While, the foliar application of 0.37 kg oxyfluorfen per ha from the 4 leaf stage is recommended for weed control in onions (Abada, 1985).

Babiker and Ahmed (1986) noted that the application of oxyfluorfen at 0.14 to 0.34 kg/ha resulted in yields comparable to the hand weeded control and when sprayed at transplanting of onion seedlings, the herbicides gave excellent and persistent control of grasses (86-100%) but were less effective on broad leaved weeds (38-94% control).

Singh *et al.* (1990) concluded that the oxyfluorfen application at 0.25 kg/ha gave maximum yield and highest weed control efficiency in onion. Singh *et al.* (1992) reported the maximum bulb yield and higher weed control efficiency with oxyfluorfen @ 0.25 kg/ha when applied 3 days before transplanting.

The highest bulb yield with the application of oxyfluorfen @ 0.25 kg/ha followed by one hand weeding at 40 DAT and the lowest weed dry weight next to pendimethalin @ 1.0 kg/ha + hand weeding at 40 DAT were reported by Singh *et al.* (1996).

2.5.3 Pendimethalin

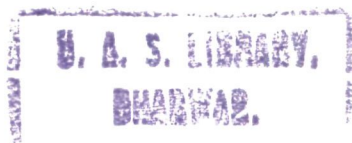
Pendimethalin at 2,3 and 4 l/ha controlled *Polygonum convolvulus* and *P.persicaria* more effectively than the standard treatment with propachlor, its greater persistence also gave better control of emerging weeds (Anon., 1978). Onion yields were not affected adversely, despite some crop injury at the higher rates.

Americanos (1980) noted that weeds in onion grown from seed or sets were effectively controlled for a period of upto 8 weeks with the pre-

emergence application of pendimethalin 175-215 g/donum (=0.33 acres) without any adverse effect on crop stand. While, Aita *et al.* (1982) reported that application of pendimethalin at 1.25 kg/ha or 1.0 kg pendimethalin + 0.5 kg linuron /ha 21 days after transplanting and before weed emergence gave the best control of both dicot weeds and *Echinochloa* Spp. Bulb yield not differ significantly from the hand weeded control.

The application of 1.2 to 1.8 kg pendimethalin/ha resulted in yields comparable to hand weeded control (Babiker and Ahmed, 1986), while Mishra *et al.* (1986) concluded that fluchloralin, pendimethalin and oxadiazon were found equally effective in controlling weeds in onion as measured by dry matter production of weeds. But higher bulb yields and weed control efficiency were achieved when two hand weedings were given and fluchloralin was applied.

Sandhu *et al.* (1987) conducted field studies over 3 years on a loamy sand soil and found that pendimethalin at 0.75 and 1.50 kg/ha applied as pre-planting or pre-emergence gave effective weed control. Bioefficacy of these herbicides when applied as pre-emergence was better than their pre-plant applications.



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The application of pendimethalin at 1.00 and 1.5 kg/ha reduced the dry matter production of weeds to a greater extent in comparison to other herbicides tested and this herbicide yielded at par with weed free treatments (Phogat *et al.*, 1989).

Govindra Singh *et al.* (1990) reported that the application of pendimethalin at 1.0 and 1.5 kg/ha was more effective against weeds than 0.5 kg/ha. But, oxadiazon at all rates was more effective in reducing weed density

and dry weight. Bulb yield of onions were increased with increase in the rates of pendimethalin.

Nandal *et al.* (1994) reported lower onion yields with pendimethalin at all the rates (1.0, 1.5 and 2.0 kg/ha) but found statistically at par with alachlor (1.5, 2.0 and 2.5 kg/ha) and both were significantly lower than the oxadiason @ 1.5 kg/ha. Verma and Singh (1996) reported maximum plant height, fresh and dry weight of plant as well as number of marketable bulbs/ha and marketable bulb yield with pendimethalin @ 1.5 kg/ha next to weed free treatment.

2.5.4 Metolachlor

Gajraj Singh *et al.* (1982) recorded the best weed control and higher yields of onion with alachlor @ 2.0 kg/ha followed by one hand weeding. Randhu - Negru *et al.* (1985) reported that the application of metolachlor after sowing though showed effective control of annual weeds, the reduction in crop growth of onion was noticed.

Hicks and Wehtje (1986) reported that high rate of application metolachlor (6.7 - 13.4 kg a.i/ha) caused crop injury. Abidin (1987) recorded the effective control of weeds and highest onion yield with metolachlor + prometryn @ 1.5-4.5 l/ha without any phototoxicity.

Keeling *et al.* (1990) noticed more than 80 per cent of yellow nut sedge control with metolachlor (PPI) but most of the annual weeds were controlled when applied as pre-emergence @ 1.0 kg/ha supplemented with one hand weeding at 30-45 days after onion emergence. Verma and Singh (1996) reported that the application of metolachlor (1.0 and 1.5 kg/ha) recorded significantly lower yield than pendimethalin, but at par with alachlor.

Maximum bulb diameter was noted with oxadiazon 1.5 kg/ha (Malik *et al.*, 1982). Govindra Singh *et al.* (1985) stated that the application of oxadiazon @ 1.0 kg/ha was more effective than other herbicides when applied either alone or followed by one manual weeding at 45 DAT of onion. One manual weeding over the application of herbicides caused the increase in bulb yield.

Patel *et al.* (1986) noticed that oxadiazon @ 1.0 kg/ha and fluchloralin @ 1.35 kg/ha were most promising and reduced the weed population by about 92 per cent as compared to unweeded control.

The pre-emergence application of oxadiazon @ 1.0 kg/ha followed by manual weeding 45 DAT showed the maximum weed control efficiency of 77 per cent compared with 60.5 per cent with oxadiazon alone and also increased the bulb yield by 81.4 per cent to 254.9 per cent over weedy check (Porwal and Singh, 1993).

2.6 PHYTOXICITY OF HERBICIDES

Phytotoxicity and movement of herbicides is related to the extent of absorption in the soil, which depends upon the organic matter, clay content and moisture content in case of pre-emergence herbicides. Kampe (1972) stated that the application of alachlor at 5 to 7 kg/ha did not cause any injury to the onion. According to Medrano *et al.* (1976), the application of oxyfluorfen at 2 l/ha or pendimethalin at 4 l/ha did not have any phototoxic effect on onion crop.

The application of pendimethalin at higher rates (4 l/ha) showed slight crop injury but onion yields were not affected adversely (Anon., 1978).

According to Americanos (1980), application of pendimethalin as pre-emergence at 175-215 g/donium (=0.33 acres) did not show any adverse effect on crop stand.

Abada *et al.* (1982) observed that the application of oxyfluorfen at rates 0.1-1.0 kg/ha in almost all the tests, burnt the leaf edges slightly, but this damage disappeared within 7-14 days after spraying and did not affect the onion yields.

Studies conducted by Anderson and Hexworth (1985) revealed that 0.125 - 1.0 lb oxyfluorfen appear to kill autumn sown onion when applied in October at the flag leaf stage, but onion seedlings began to appear on 1 March on plots given the lowest rates and at later dates with higher rates of applications.

Magyar (1985) noted that high doses of oxyfluorfen were likely to cause stand reductions in onion crop. While, Babiker and Ahmed (1986) found that none of the herbicides (Oxadiazon, pendimethalin, Oxyfluorfen and chlorthalidimethyl) produced any visible symptoms of damage to onion when sprayed at planting.

TamilSelvan *et al.* (1990) noticed that post-sowing application (3 days after sowing) of oxyfluorfen at 0.1-0.6 kg/ha were more phytotoxic to onion, with damage lasting for upto 2 weeks. The highest rates of lactofen (0-0.288 kg/ha) and clopropoxydim (0-1.08 kg/ha) chemicals caused phytotoxic symptom in onion with rapid recovery of the surviving plants. These herbicides did not affect sprouting, weight loss or bulb deterioration during storage (Gomes *et al.*, 1991). While, pendimethalin + oxadiazon were least damaging treatments to onion crop (Grozdenovic Varga *et al.*, 1992). Pre-sowing

incorporation of fluchloralin was found to be phytotoxic to crop resulting in low crop density and bulb yield (Nadagouda, 1995).

2.7 WEED CONTROL EFFICIENCY

Patel *et al.* (1986) found that pre-plant incorporation of fluchloralin @ 0.9 kg/ha + weeding at 40 DAT found effective in reducing weed dry weight and increased the weed control efficiency (92.1) and registered the higher bulb yield.

Hanumanthraju (1992) opined that pre-emergence application of oxfluorfen @ 0.35 kg/ha was more effective in minimizing the weed population, weed dry weight and recorded higher weed control efficiency (84.5). At Dharwad, Nadagouda (1995) reported the lowest weed population, weed dry weight, highest weed control efficiency and bulb yield with pre-emergence application of pendimethalin @ 1.0 kg/ha. While, lowest weed population, weed dry weight, higher weed control efficiency and garlic bulb yield were noticed with pendimethalin @ 1.0 kg/ha + one inter cultivation and hand weeding at 30 DAS (Nekar, 1997).

2.8 GROWTH AND DEVELOPMENT

Leaf area duration is one of the growth components which has been shown to have direct effect on yield and dry matter production (Watson, 1952; Watson, 1956; Welbank *et al.*, 1966 and Donald, 1962). Power *et al.* (1967) observed that LAD is correlated with dry matter production and consequently, any practice that increase the longevity of green leaves should increase the dry weight of plants.

Abe *et al.* (1955) found that onion cultivars are best adopted in regions where the temperature and photoperiodic requirements are minimum for

bulbing. In these conditions, leaf growth and bulb formation would be prolonged and high yield might be expected since there will be extended LAD during bulbing phase (Watson, 1952).

Leaf area ratio (LAR) is a morphological index of plant (leaf area per unit dry weight of the plant) which is closely connected with the photosynthetic activity of the leaves (Evans, 1972).

Brewster (1979) observed that LAR tend to decrease with plant size and is negatively correlated with \log_e dry weight and time. He also found that LAR increased between 10° and 27°C, but decreased at 31°C. Between 10° and 19°C, the increase in LAR were proportionately less than those in RGR and therefore, NAR also increased between 10° and 19°C. Similar increase in NAR (Eagles, 1967, Scaife, 1973) and LAR (Hughes, 1965, Eagles, 1967; Rajan *et al.*, 1973) with temperature have been reported in other species.

Nichiporovich (1960) was of the opinion that NAR increased rapidly from emergence to a stable optimum level with a decline at the end of growing period. Williams (1946) and Thorne (1960) however, found that NAR of all the species based on leaf area, fell linearly with time.

Robinson (1973) in a study of two onion cultivars "Dewidt" and "Texas Grano" sown at monthly intervals from February to June found that mean NAR rose with successive sowing dates and that of Dewidt being the higher.

Shekar (1974) reported that NAR was maximum at seventh day after transplanting and it decreased rapidly upto 52 days and increased gradually thereafter upto 97 days after transplanting. He also found that increase in NAR after 52 days coincided with the rapid increase in bulb growth and it increased slightly coinciding with bulb initiation and development stage.

Brewster (1977) found that the NAR of onion seedlings was $0.54 \text{ g m}^{-2} \text{ day}^{-1}$. In his later studies, Brewster (1979), found that between 10° and 19°C temperatures, NAR increased and between 19° and 27°C increase in LAR was compensated for by decrease in NAR with the result that relative growth rate (RGR) showed little difference.

Increase in growth rate by any treatment occurs mainly due to increase in the leaf area and the NAR is of secondary importance in determining CGR (Watson, 1952). Shekar (1974) found that CGR reached a maximum level on 82nd day after transplanting onion. During *kharif* season, CGR at 67th and 97th day was significantly higher than at other periods except on 82nd day.

2.9 PHYSIOLOGICAL AND BIOCHEMICAL PARAMETERS

The influence of various herbicides on physiological and biochemical parameters in onion is lacking. However, an attempt has been made to collect the information on various physiological and biochemical parameters in onion.

Though chlorophyll content is one of the chief factors in photosynthesis, still it is surprising to find that it has a weak influence on photosynthesis when it is abundant. Emerson *et al.* (1940) found that with other external conditions being optimum, the ratio of chlorophyll molecules present to molecules of carbon dioxide reduced (photosynthesis) was not constant but depended on its previous growth and age of the culture. Ferry and Ward (1959) stated that chlorophyll content is not considered to be a limiting factor in the photosynthetic rate of plants unless it is greatly reduced by mineral deficiency. According to Leopold (1964), eventhough chlorophyll is essential for photosynthesis, the abundance of this pigment surprisingly exerted a weak influence on photosynthesis in the field.

Kharchenko (1970) observed in onion plants that maximum photosynthesis and chlorophyll pigment occurred in bulb crop during bulb formation and in seed crop during flowering. Gencev (1970a) in determinations of chlorophyll in three years of onion cultivation observed that maximum chlorophyll content was reached at about 30 days after sprouting during the first year and in the second year crop, this took place at 12 to 15 days after the beginning of strong growth. The maximum chlorophyll content in the third year lasted throughout. He also found that chlorophyll "a" and "b" was about 3:1 and change in the pigment content during ontogenesis resulted mainly from the change in chlorophyll a. In his later studies, Gencev (1970b) found that chlorophyll content of different parts of leaves and different leaves varied considerably and there existed a positive correlation between chlorophyll content and peroxidase and catalase activity as well as vitamin C content.

Whiteside *et al.* (1975) analysed chlorophyll, carbohydrates, protein and total dry weight at different growth stages of onion and found that all the parameters were maximum at 21 weeks and declined rapidly then onwards.

2.10 ECONOMICS OF WEED CONTROL METHODS

Yaduraj *et al.* (1980) reported that fluchloralin @ 1.0 kg ha⁻¹ + hand weeding resulted in the highest net returns per rupee spent (Rs.34) against the weed free check (Rs.21.6). The net profit was higher with alachlor than with other herbicides or with hand weeding (Kulandaivelu and Sankaran, 1991).

Sonone *et al.* (1982) asserted that the application of nitrofen @ 2.0 kg/ha + one hand weeding at 45 DAT gave highest yield of onion bulbs and net additional returns per hectare followed by fluchloralin @ 1.0 kg/ha + one hand weeding at 45 DAT.

Patel *et al.* (1986) found that the application of fluchloralin @ 0.9 kg/ha + one hand weeding gave the highest additional income compared to unweeded control. But the cost benefit ratio was highest with the oxadiazon @ 0.50 kg/ha.

Patel *et al.* (1987) stated that spraying of fluchloralin @ 0.9 kg/ha as pre-planting + nitrofen @ 1.25 kg/ha as post-emergence 15 days after transplanting was found most effective and economical. This treatment yielded 37.56 q/ha mean bulb yield which was comparable with the yield of local method (38.49 q/ha) giving maximum net return of Rs.10681/ha.

Praveen Rao *et al.* (1987) reported the negative response when weed control was not taken up. It had reduced the yield by 70 per cent and had low (0.07) cost: benefit ratio. Rupee profit per rupee spent on weed control was highest with oxyfluorfen @ 0.15 kg/ha as pre-emergent herbicide (Hanumanthraju, 1992).

Nadagouda (1995) concluded that net return per rupee spent on weed control was highest with tank mixture of pendimethalin (1.50 kg/ha)+ fluchloralin (0.50 kg/ha), but highest benefit:cost ratio with pendimethalin @ 1.0 kg/ha + hand weeding at DAS. In garlic, Nekar (1997) obtained highest net income with weed free check followed by one intercultivation and hand weeding at 30 DAS and two hand weedings at 30 DAS and pendimethalin (1.0 kg/ha).

MATERIAL AND METHODS

III. MATERIAL AND METHODS

A field experiment was conducted to study the physiological basis of weed control efficiency in onion during *kharif* 1999, at the Main Research Station, University of Agricultural Sciences, Dharwad (Karnataka) under rainfed conditions. The details of materials used and the experimental techniques adopted during the course of investigation are presented in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was conducted at the Main Research Station, UAS, Dharwad in F block located at 15°26' N latitude, 75°07' E longitude and an altitude of 678 m above the mean sea level. This research station comes under northern transitional zone (zone-8) of Karnataka and lies between the western hilly zone (zone-9) and eastern northern zone (zone-3).

3.2 SOIL CHARACTERS OF THE EXPERIMENTAL SITE

The experiment was laid out on black clay loam soil. Composite soil samples were collected from the experimental site at a depth of 0 to 30 cms before sowing and were analysed for various physical and chemical characteristics. The data of soil analysis along with methods employed are furnished in Table 1.

3.3 CLIMATIC CONDITIONS

The monthly meteorological data of rainfall, temperature and relative humidity for the year 1999 and the average for the past 48 years (1950-1997) as recorded at Meteorological Observatory of the Main Research Station, UAS, Dharwad are furnished in Table 2 and depicted in the Figure 1. The average

Table 1. Physical and chemical properties of soil of the experimental site

	Particulars	Value obtained	Method used
I.	Physical properties		
	Coarse sand (%)	6.10	International pipette method (Piper, 1966)
	Fine sand (%)	12.90	International pipette method (Piper, 1966)
	Silt (%)	27.20	International pipette method (Piper, 1966)
	Clay (%)	53.80	International pipette method (Piper, 1966)
	Field capacity (%)	31.80	Field Method (Dastane, 1967)
	Bulk density (g/cc)	1.27	Coarse sampler method (Dastane, 1967)
II.	Chemical properties		
	Available N (kg ha ⁻¹)	282.60	Alkaline permanganate method (Subbiah and Asija, 1966)
	Available P ₂ O ₅ (kg ha ⁻¹)	38.30	Olsen's Method (Jackson, 1973)
	Available K ₂ O (kg ha ⁻¹)	382.20	Flame photometer (Jackson, 1973)
	Organic carbon (%)	0.53	Wet oxidation method (Jackson, 1973)
	pH (1:2.5)	7.60	pH meter (Piper, 1966)
	EC (dSm ⁻¹)	0.20	Conductivity bridge (Jackson, 1973)

Table 2. Meteorological data from January 1999 to October 1999 and the average of past 48 years (1950-1997) recorded at Main Research Station, University of Agricultural Sciences, Dharwad

Months	Average Rainfall (mm)		Mean temperature (°C)			Mean monthly relative humidity (%)	
	1950-97	1999	Maximum		Minimum	1950-97	1999
			1950-97	1999			
January	0.11	0.0	29.15	29.4	14.11	62.88	75.00
February	0.00	0.0	34.76	32.80	15.94	50.82	63.00
March	7.77	0.0	35.76	36.20	18.76	56.48	63.00
April	49.51	14.7	37.09	36.60	21.37	79.10	65.00
May	87.62	32.8	36.75	32.20	21.45	67.10	75.00
June	112.96	71.8	29.47	28.00	21.20	81.77	85.00
July	156.03	113.9	27.05	27.50	20.96	88.37	86.00
August	102.37	19.7	27.10	27.70	20.64	86.83	84.00
September	104.13	8.8	28.75	28.20	20.16	83.24	80.00
October	136.62	161.1	30.17	28.60	19.22	76.26	85.00
November	35.04		29.37		15.33	68.44	
December	6.08		29.17		13.41	64.69	

rainfall (past 48 years) was 801.0 mm which was fairly distributed from April to November. The rainfall had two peaks, one in July and the other in October. The mean maximum temperature varied from 27.05°C (July) to 36.60°C (April). Whereas, mean minimum temperature ranged from 13.41°C (December) to 21.30°C (May). The mean monthly maximum and minimum relative humidity was 86.00 per cent (July) and 63.00 per cent (February), respectively.

The total rainfall for the year 1998-99 was 411.99 mm as against the normal rainfall of 798.24 mm (past 48 years) which is more to the extent of 386.25 mm.

The highest and lowest mean maximum temperature during the crop period were 36.60 (April) and 27.50 (July). While the highest and lowest mean minimum temperature were 21.10°C (April) and 20.10°C (October), respectively.

3.4 PREVIOUS CROP

Chilli was grown during the *kharif* of 1997-98 with uniform cultural practices in the experimental area.

3.5 EXPERIMENTAL DETAILS

The experiment consisted of five pre-emergence herbicides each at two doses, a weed free check and a control (weedy check). Totally there were 12 treatments and the details of the treatments are given below.

3.5.1 Treatments

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- T₁ - Alachlor (1.0 kg a.i./ha) pre-emergent
- T₂ - Alachlor (1.5 kg a.i./ha) pre-emergent
- T₃ - Oxyfluorfen (0.15 kg a.i./ha) pre-emergent
- T₄ - Oxyfluorfen (0.2 kg a.i./ha) pre-emergent
- T₅ - Pendimethalin (1.0 kg a.i./ha) pre-emergent
- T₆ - Pendimethalin (1.5 kg a.i./ha) pre-emergent
- T₇ - Oxadiazon (0.4 kg a.i./ha) pre-emergent
- T₈ - Oxadiazon (0.5 kg a.i./ha) pre-emergent
- T₉ - Metolachlor (1.0 kg a.i./ha) pre-emergent
- T₁₀ - Metolachlor (1.5 kg a.i./ha) pre-emergent
- T₁₁ - Weed free check
- T₁₂ - Weedy check

3.5.2 Description of Herbicide used in the experiment

3.5.2.1 Alachlor (C₁₄H₂₀ClNO₂)

Chemical name : 2-chlor-2', 6' diethyl-N-(methoxymethyl) - acetanilide

Trade name : Lasso

Properties

Pure alachlor is a cream coloured solid having melting point at 39.5 to 41.5°C, solubility (25°C) with 242 mg/l water, soluble in acetone, benzene, ethanol, ethyl acetate but sparingly soluble in heptane, hydrolysed under strong acid alkaline conditions.

Mode of action

It is absorbed primarily between seed and first node of germinating seedling. It inhibits seedling emergence and root and shoot growth.

Uses

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It is a selective pre-emergent or early post-emergent herbicide used at 1.68 to 4.48 kg/ha to control annual grasses and many broad leaved weeds in chilli, brassica, maize, oilseed rape, peanuts, raddish, soybean and sugarcane.

Formulation

Emulsifiable concentration (50% EC) and granular forms.

3.5.2.2 Metolachlor (C₁₅H₂₂ClNO₂)

Chemical name : 2-chloro-N- (2-ethyl-6-methylphenyl)-N-(2- methoxy-1-1 methylethyl) - acetamide.

Trade name : Dual

Properties

It is a colourless liquid, hydrolyzed by strong alkalies and strong mineral acids.

Mode of action

Selective soil applied herbicide, absorbs predominantly by hypocotyl and coleoptile, inhibits germination.

Uses

It is used as selective soil herbicide for both pre-emergence and pre-plant control of weeds (mainly grasses) in cotton, maize, potato, peanut, soybean, safflower, sorghum and woody ornamentals.

Formulations : Emulsifiable concentration (50% EC).

3.5.2.3 Pendimethalin (C₁₃H₁₉N₃O₄)

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Chemical name : N-(1-ethyl-propyl)-3,4-dimethyl-2,6-dinitro benzenamine

Trade name : Stomp

Properties

It has an orange yellow colour with odourless crystals and high solubility. It is also reported to be stable to acids and alkalies and slowly decomposed by light.

Mode of action

It is selective soil applied herbicide, predominantly used for pre-emergence treatment. Inhibits seed germination or destroys the seedling.

Uses

Used for pre-emergence control of annual broad leaved weeds, annual meadow grass and black grass in winter barley, wheat and rye. Pre or post-emergence control of weeds in sorghum and rice. Pre-plant incorporation for control in cotton, peanuts, soybean, sunflower and tobacco. Control of germinating annual weeds in strawberries.

Formulation : Emulsifiable concentration (30% EC).

3.5.2.4 Oxadiazon (C₁₅H₁₈Cl₂N₂O₃)

Chemical name : 5 - tert-butyl-3-(2,4-dichloro-5 isopropoxyphenyl)-1, 3, 4-oxadiazol-2-one.

Trade name : Ronstar, G-315, 17623 RP

Properties

It is white in colour, non-hygroscopic, crystalline, odourless, having molecular weight 345.2 with melting point of 90°C. Solubility in water is about 0.0007 g/l and in methanol about 100 g/l.

The action is quick and complete when weeds young or are growing fast, it diffuses rapidly in growing tip ensuring total destruction. Light is necessary for herbicidal action.

Uses

It is primarily used as pre-emergence herbicide as well as post-emergence. It is particularly useful to control weeds that grow from bulbs, rhizomes or other deep rooted propagules. As post-emergence, it is active during the early stages of growth of weeds. It is used in rice, cotton, sugarcane, soybean, peanut, onion, garlic, potato, sunflower, transplanted vegetables, tea, rubber and banana.

Formulation : Emulsifiable concentration (25% EC).

3.5.2.5 Oxyfluorfen (C₁₅H₁₁ClF₃NO₄)

Chemical name : 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene.

Trade name : Goal, RH2615

Properties

It is dark brown liquid with melting point of 84-85°C. Soluble in most of the organic solvents and in water less than 1 ppm at 25°C. It is orange crystalline solid at room temperature.

Mode of action

It is used as pre and post-emergence herbicide.

LEGEND

Treatments (Herbicides)

T ₁	-	Alachlor (1.0 kg a.i./ha)	Pre-emergent
T ₂	-	Alachlor (1.5 kg a.i./ha)	Pre-emergent
T ₃	-	Oxyfluorfen (0.15 kg a.i./ha)	Pre-emergent
T ₄	-	Oxyfluorfen (0.2 kg a.i./ha)	Pre-emergent
T ₅	-	Pendimethalin (1.0 kg a.i./ha)	Pre-emergent
T ₆	-	Pendimethalin (1.5 kg a.i./ha)	Pre-emergent
T ₇	-	Oxadiazon (0.4 kg a.i./ha)	Pre-emergent
T ₈	-	Oxadiazon (0.5 kg a.i./ha)	Pre-emergent
T ₉	-	Metolachlor (1.0 kg a.i./ha)	Pre-emergent
T ₁₀	-	Metolachlor (1.5 kg a.i./ha)	Pre-emergent
T ₁₁	-	Weed free check	
T ₁₂	-	Weedy check	

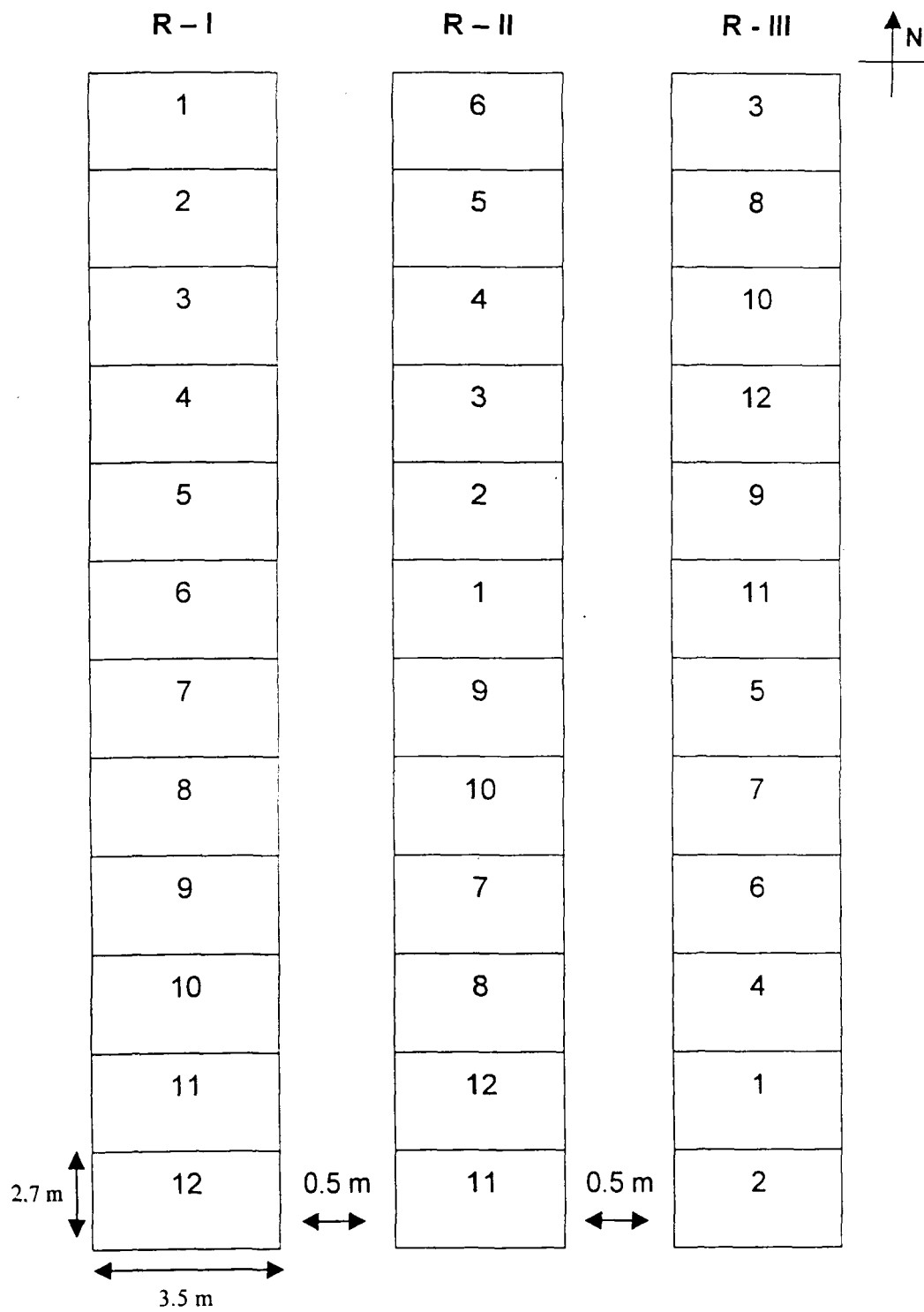


FIGURE 1: PLAN OF LAYOUT OF THE EXPERIMENT

Selective herbicide for pre-emergence and or post-emergence control of certain annual broad leaf and grassy weeds. Registered for use in avocados, broccoli, cabbage, cauliflower, citrus, coffee, conifers, corn, cotton, mint, nut crops, olives, onion and tree fruits (Stone fruit, pome fruit).

Formulation : Emulsifiable concentration (23.5% EC)

3.5.3 Design and layout

The experiment was laid out in a randomized block design with three replications as depicted in the Fig.1.

3.5.4 Plot size

Gross plot : 3.5 m x 2.7 m = 9.45 m²

Net plot : 3.15 m x 1.7 m = 5.36 m²

3.5.5 Variety

Onion : Nasik red (N-53)

3.6 CULTURAL OPERATIONS

3.6.1 Land preparation

The land was ploughed once with mould board plough and harrowed twice to bring the soil to a fine tilth. Stubbles and weeds were cleared from the experimental area and smoothened with wooden plank to prepare a fine seed bed.

3.6.2 Fertilizer application

Nitrogen, phosphorus and potassium were applied at the rate of 125:50:120 kg N, P₂O₅ and K₂O per hectare in the form of urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. Entire quantity of phosphorus and potassium and 50 per cent of nitrogen was applied at the time of sowing in furrows. Remaining 50 per cent of nitrogen was top dressed in the form of urea five weeks after sowing.

3.6.3 Sowing

The experimental plots were demarcated as per the plan of layout well in advance. Plots were marked with the help of marker at a spacing of 22.5 cm from row to row and 7.5 cm from plant to plant. Seeds of onion were sown (20.06.1999) directly in the furrows and covered with soil.

3.6.4 Imposition of treatments

The pre-emergence herbicides viz., alachlor, metolachlor, pendimethalin, oxyfluorfen and oxadiazon were sprayed uniformly on the same day after sowing with the help of knapsack sprayer fitted with WFN nozzle using a spray volume of 1000 litre of water per hectare.

Different herbicides were compared with weed free check and weedy check to evaluate the comparative efficacy of different herbicides which were superimposed with one hand weeding at 45 days after sowing.

3.6.5 Plant protection measures

The schedule of different plant protection measures taken up during the period of investigation is as follows.

	Chemical used	Concentration	Against
1.	Monocrotophos (36%EC) + Dicofol	2.5 ml/l each	Thrips,mites and aphids
2.	Endosulfan(35%EC)	2.0 ml/l	Borers
3.	Captan (50% WP)	2.0 g/kg seeds	Sclerotium sp.

3.6.6 Harvesting

Onion was harvested on 25.10.99. The maturity indices were judged based on changes in colour of leaves, as they turned yellowish and the necrotic leaf tips on the normal green coloured leaves. The plants were uprooted from the net plot area of each plot separately. Bulbs were separated from the leaves at the point of neck, which is a constricted portion of the plant. Soil particles adhering to the bulbs were removed.

3.7 OBSERVATIONS ON WEEDS

3.7.1 Weed population

The number of weeds present in each treatment in 0.25 m² area selected at random each time were counted at 30,45, 60, 90 DAS and at harvest. They are further classified into monocots and dicots before subjecting to total analysis.

3.7.2 Dry weight of weeds (g/m²)

Dry weight of weeds were recorded at periodical intervals, viz., 30,45, 60, 90 DAS and at harvest. The weeds were uprooted from the 0.25 m² area selected at random each time and were oven-dried to a constant weight at 80°C. The dry weight of weeds were expressed as g/m².

3.7.3 Weed index (%)

Weed index is the reduction in crop yield due to the presence of weeds in comparison with weed free plot expressed as percentage. In other words, weed index expresses the competition offered by weeds measured by per cent reduction in yield owing to their presence in the field.

$$\text{Weed index (\%)} = \frac{x - y}{x} \times 100$$

Where, X = Total yield from the weed free plot

Y = Total yield from the treatment for which weed index has to be calculated.

3.7.4 Weed control efficiency (%)

This denotes the magnitude of weed reduction due to the weed control treatments. Weed control efficiency was calculated by using the formula given by Patel *et al.* (1987).

$$\text{WCE(\%)} = \frac{\text{Weed dry weight in unweeded control} - \text{Weed dry weight of treatment}}{\text{Weed dry weight of unweeded control}} \times 100$$

3.7.5 Weed control and crop toxicity rating

Visual ratings (Table 3) were made at 15, 30, 45, 60, 75, 90 DAS and at harvest to know the extent of weed control and the extent of toxicity caused by different herbicides on crop as given by Rao (1986).

Weed control and crop toxicity rating were made from one to ten points scale as given in Table 6 and 5.

Table 3. Qualitative description of treatment effects on weeds and crop in the visual scoring scale (0 to 10)

Effect	Rating	Weed	Crop
None	0	No control	No injury, normal
Slight	1	Very poor control	Slight stunting, injury or discoloration
	2	Poor control	Some stand loss, stunting or discoloration
Moderate	3	Poor to deficient control	Injury more pronounced but not persistent
	4	Deficient control	Moderate injury, recovery possible
	5	Deficient to moderate control	Injury more persistent, recovery doubtful
Severe	6	Moderate control	Near severe injury no recovery possible
	7	Satisfactory control	Severe injury stand loss
	8	Good control	Almost destroyed, a few plants surviving
Complete	9	Good to excellent control	Very few plants alive
	10	Complete control	Complete destruction

Rao (1986)

3.8 MORPHOLOGICAL-PHYSIOLOGICAL CHARACTERS

3.8.1 Leaf area

Linear measurements were made for the calculation of leaf area at 30, 60, 90 and 120 DAS. The leaf area was calculated by using the following formula (Mahesh Babu, 1984).

$$\text{Leaf area (cm}^2\text{)} = \text{Leaf length (cm)} \times 2 \text{ Breadth (cm)} \times 0.7865$$

3.8.2 Dry weight of leaf

Dry weight of leaf was recorded at 30, 60, 90 and 120 DAS from the samples collected for recording various morpho-physiological characters and expressed as g plant⁻¹.

3.8.3 Dry matter production and its distribution

Dry matter accumulation in various plant parts (Shoot and bulb portion) and the total dry matter were recorded after drying the samples in hot air oven at 80°C for 72 hours.

3.9 GROWTH ANALYSIS

3.9.1 Leaf Area Index (LAI)

Leaf area index is defined as the leaf area produced by plant per unit land area and was calculated by the following formula (Sestak *et al.*, 1972).

$$\text{LAI} = \frac{\text{Leaf area/plant (cm}^2\text{)}}{\text{Land area/plant (cm}^2\text{)}}$$

3.9.2 Crop Growth Rate (CGR)

Crop growth rate is the rate of dry matter production per unit ground area per unit time (Watson, 1952). It was calculated by using the following formulae and expressed as $\text{g m}^{-2} \text{ day}^{-1}$.

$$\text{CGR (g m}^{-2}\text{d}^{-1}) = \frac{W_2 - W_1}{(t_2 - t_1)} \times \frac{1}{p}$$

Where, W_1 = Dry weight of the plant (g m^{-2}) at time t_1

W_2 = Dry weight of the plant (gm^{-2}) at time t_2

$(t_2 - t_1)$ = Time interval in days

P = Unit land area (m^2)

3.9.3 Absolute Growth Rate (AGR)

It expresses the dry weight increase per unit time and was calculated by using the following formula and expressed as g day^{-1} (Radford, 1967).

$$\text{AGR (g plant}^{-1}\text{d}^{-1}) = \frac{W_2 - W_1}{(t_2 - t_1)}$$

Where, W_2 and W_1 are the total dry weights per plant at time t_2 and t_1 , respectively.

3.9.4 Relative Growth Rate (RGR)

It is the ratio of increase in dry weight per unit dry weight already present and is expressed in $\text{g g}^{-1} \text{ day}^{-1}$. Relative growth rate at various stages was calculated as suggested by Radford (1967).

$$\text{RGR (g g}^{-1}\text{day}^{-1}) = \frac{\log_e W_2 - \log_e W_1}{(t_2 - t_1)}$$

Where, W_1 = Dry weight of plants (g) at time t_1

W_2 = Dry weight of plants (g) at time t_2

$(t_2 - t_1)$ = Time interval in days

3.9.5 Net Assimilation Rate (NAR)

Net assimilation rate is the rate of dry weight increase per unit leaf area per unit time. It was calculated by the following formula (Watson, 1952) and expressed as $\text{mg dm}^{-2} \text{d}^{-1}$.

$$\text{NAR (g dm}^{-2}\text{d}^{-1}) = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\log_e W_2 - \log_e W_1)}{(L_2 - L_1)}$$

Where, L_1 and W_1 = Leaf area (dm^2) and dry weight of the plant (g), respectively at time t_1 .

L_2 and W_2 = Leaf area (dm^2) and dry weight of the plant (g), respectively at time t_2 .

$(t_2 - t_1)$ = Time interval in days

3.9.6 Leaf Area Duration (LAD)

Leaf area duration is the integral of leaf area index over a growth period (Watson, 1952). LAD for various periods was worked out as per the formula of Power *et al.* (1967) and expressed in days.

$$\text{LAD (days)} = \frac{L_i + (L_i + 1)}{2} \times (t_2 - t_1)$$

Where, L_i = LAI at i^{th} stage

$L_i + 1$ = LAI at $(i + 1)^{\text{th}}$ stage

$(t_2 - t_1)$ = Time interval in days

3.9.7 Specific Leaf Weight (SLW)

The specific leaf weight indicates the leaf thickness and was determined by the method of Radford (1967), it was expressed as mg cm^{-2} .

$$\text{SLW (mg cm}^{-2}\text{)} = \frac{\text{Leaf dry weight (mg)}}{\text{Leaf area (cm}^2\text{)}}$$

3.9.8 Specific Leaf Area (SLA)

The inverse of the specific leaf weight is the specific leaf area and was calculated as follows.

$$\text{SLA (cm}^2 \text{mg}^{-1}\text{)} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Leaf dry weight (mg)}}$$

3.9.9 Leaf Area Ratio (LAR)

The leaf area ratio was calculated as per the following formula.

$$\text{LAR (cm}^2 \text{g}^{-1}\text{)} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Total dry matter (g)}}$$

3.9.10 Biomass Duration (BMD)

The BMD was calculated by using the following formula and expressed in g days.

$$\text{BMD (g days)} = \frac{\text{TDM (T}_1) + \text{TDM (T}_2)}{2} \times (t_2 - t_1)$$

where, TDM(T₁) = TDM at t₁ stage

TDM(T₂) = TDM at t₂ stage

(t₂-t₁) = Time interval between two stages in days

3.10 BULB YIELD

From each net plot area, ten matured plants were selected at random and the fresh weight of bulbs was recorded for expressing on plant basis. For expressing on hectare basis, bulbs collected from the net plot area was used.

3.11 BIOCHEMICAL PARAMETERS

3.11.1 Estimation of chlorophyll content

The chlorophyll content was measured by following the method of Arnon (1949). 0.25 g of fresh leaves were cut into small pieces and homogenized with pure acetone in a mortar with pestle. The supernatant was decanted through Whatman No.42 filter paper into a 25 ml volumetric flask. Then 80 per cent acetone is added to the residue in the mortar and the extraction was repeated until residue is decolourised. Then volume was made upto 25 ml with 80 per cent acetone and the absorbance of the extract was measured at 663, 645 nm in spectrophotometer (Systronics, UV-VIS spectrophotometer 108) using 80 per cent acetone as blank. The total chlorophyll content was estimated in leaves at 60 and 90 DAS by using the following formula.

$$\text{Total chlorophyll (mg g fr. wt}^{-1}\text{)} = 20.2 (A_{645}) - 8.02 (A_{663}) \times \frac{V}{1000 \times w \times a}$$

where, A_{645} = Absorbance of the extract at 645 nm
 A_{663} = Absorbance of the extract at 663 nm
 A = Path length of Cuvette (1 cm)
 V = Final volume of the Chlorophyll extract (ml)
 W = Fresh weight of the sample (g)

3.12 ECONOMICS OF WEED CONTROL

The market price of the produce at the time when produce was ready for sale was obtained from the Agriculture Produce Marketing committee (APMC), Hubli. The income from bulb yield and cost of cultivation for individual treatment was used for calculating the net income and was expressed in rupees per hectare.

3.13 STATISTICAL ANALYSIS AND INTERPRETATION OF DATA

Fisher's method of analysis and interpretation of data as given by Panse and Sukhatme (1967) was used. The level of significance used in "F" and "t" tests was equal to 0.05. Critical differences were calculated wherever "F" test was significant.

3.14 TRANSFORMATION

The data on weed count and weed weight have shown high degree of variation. A linear relationship between the means and variance was observed and therefore, the data on weed count was subjected to $(X+1)^{1/2}$ transformation while the data on weed weight was subjected to $\log (X+1)$ transformation to make analysis of variance valid as suggested by Bartlett (1947) and Blackman and Roberts (1950).

Table 4. Common weeds noticed in the experimental plot

Weed species	Common name	Family
Monocotyledonous weeds		
<i>Cynodon dactylon</i> Pers.	Bermuda grass	Poaceae
<i>Dinebra retroflexa</i> Panz.	-	Poaceae
<i>Cyperus rotundus</i> L.	Nut sedge	Cyperaceae
Dicotyledonous weeds		
<i>Abutilon indicum</i> G.. Don.	-	Malvaceae
<i>Acanthospermum hispidum</i> Dc.	Starbur	Compositae
<i>Ageratum conyzoides</i> L.	Bill goat weed	Compositae
<i>Alternanthera sessilli</i> L.		
<i>Amaranthus viridis</i> L.	Pigweed	Amaranthaceae
<i>Borreria</i> sp. (L..F.) Fn-Will	-	Nyctaginaceae
<i>Cynotis cristata</i>	-	Commelinaceae
<i>Commelina bengalensis</i> L.	Tropical spider wort	Commelinaceae
<i>Desmodium diffusum</i> Dc.	Telegraphic plant	Leguminaceae
<i>Digeria arvensis</i> L.	-	Amaranthaceae
<i>Euphorbia</i> Spp. L.	Milky weed	Euphorbiaceae
<i>Lagasca mollis</i> Cav.	-	Asteraceae
<i>Phyllanthus niruri</i> L.	-	Euphorbiaceae
<i>Portulaca oleraceae</i>	Purslane	Portulacaceae
<i>Trichoderma indicum</i>	-	Boraginaceae

EXPERIMENTAL RESULTS

VI. EXPERIMENTAL RESULTS

A field experiment was conducted during *kharif* 1999 to study the effect of herbicides and crop weed competition on morpho-physiological traits, weed control efficiency and yield components in direct seeded onion at Main Research Station, University of Agricultural Sciences, Dharwad. The results obtained in the present investigation are described in this chapter.

4.1 STUDIES ON WEED CONTROL RATING, WEED FLORA AND CROP TOXICITY

4.1.1 Phytotoxicity ratings

The data on phytotoxic effects of various herbicides was evaluated and presented in Table 5. The phytotoxic effects were relatively more during early stages of crop growth and decreased during later phases of crop development. During early stage of crop growth (15 DAS) the herbicide treatments Oxadiazon @ 0.4 kg a.i. ha⁻¹ recorded significantly lowest phytotoxicity ratings followed by oxadiazon @ 0.5 kg a.i. ha⁻¹. However, the herbicide treatments, oxyfluorfen @ 0.2 kg a.i. ha⁻¹, pendimethalin @ 1.5 kg a.i. ha⁻¹, metolachlor @ 1.5 kg a.i. ha⁻¹ and oxyfluorfen @ 0.15 kg a.i. ha⁻¹ registered higher values of phytotoxicity ratings (4.67 to 4.00).

Similarly at 30 DAS, the treatment oxadiazon @ 0.4 kg a.i. ha⁻¹ registered lowest values for phytotoxicity (0.0) followed by oxadiazon @ 0.5 kg a.i. ha⁻¹ (0.33) as compared to other treatments. The treatment pendimethalin @ 1.5 kg a.i. ha⁻¹, oxyfluorfen @ 0.2 kg a.i. ha⁻¹ and oxyfluorfen @ 0.15 kg a.i. ha⁻¹ showed significantly higher values for phytotoxic ratings (<4.00).

Table 5. Effect of herbicides on phytotoxic ratings at different growth stages in onion

Treatments	15 DAS	30 DAS	45 DAS	60 DAS
1. Alachlor (1.0 kg a.i/ha)	3.33	2.33	1.33	0.33
2. Alachlor (1.5 kg a.i/ha)	3.67	2.67	1.67	0.67
3. Oxyfluorfen (0.15 kg a.i/ha)	4.00	3.33	2.00	1.00
4. Oxyfluorfen (0.20 kg a.i/ha)	4.67	3.67	2.33	1.33
5. Pendimethalin (1.0 kg a.i/ha)	3.67	2.33	1.00	0.00
6. Pendimethalin (1.5 kg a.i/ha)	4.33	4.00	1.33	0.00
7. Oxadiazon (0.4 kg a.i/ha)	0.33	0.00	0.00	0.00
8. Oxadiazon (0.5 kg a.i/ha)	0.67	0.33	0.00	0.00
9. Metolachlor (1.0 kg a.i/ha)	3.67	3.33	1.67	0.33
10. Metolachlor (1.5 kg a.i/ha)	4.00	3.00	2.00	0.67
11. Weed free	0.00	0.00	0.00	0.00
12. Weedy check	0.00	0.00	0.00	0.00
SEm ±	0.32	0.35	0.32	0.22
CD at 5%	0.95	1.02	0.95	0.65

At 45 DAS, the treatments oxadiazon @ 0.4 and 0.5 kg a.i. ha⁻¹ registered lowest phytotoxic ratings (0.0) and this was highest with oxyfluorfen @ 0.2 kg a.i. ha⁻¹, oxyfluorfen @ 0.15 kg a.i. ha⁻¹ and metolachlor @ 1.5 kg a.i. ha⁻¹ (<2.33). Similarly at 60 DAS, the treatments pendimethalin @ 1.0 kg a.i. ha⁻¹, pendimethalin @ 1.5 kg a.i. ha⁻¹, oxadiazon @ 0.4 kg a.i. ha⁻¹, oxadiazon @ 0.5 kg a.i. ha⁻¹ recorded significantly lowest values for phytotoxicity. Whereas, oxyfluorfen @ 0.2 kg a.i. ha⁻¹ recorded higher values for phytotoxicity (1.33).

4.1.2 Weed control ratings

The data pertaining to weed control rating (WCR) at different growth stages in onion indicated significant differences due to herbicide treatments (Table 6). At 30 DAS, the weed control rating (WCR) was significantly higher in oxadiazon @ 0.5 kg a.i. ha⁻¹ (9.33) followed by oxadiazon @ 0.4 kg a.i. ha⁻¹ (9.00) and pendimethalin @ 1.5 kg a.i. ha⁻¹ (8.33) as compared to weedy check (0.00). However, the WCR was found to be lowest in metolachlor @ 1.0 kg a.i. ha⁻¹ (3.00) followed by metolachlor @ 1.5 kg a.i. ha⁻¹ (3.67) and Alachlor @ 1.0 kg a.i. ha⁻¹ (3.69).

The treatment Oxadiazon @ 0.5 kg a.i. ha⁻¹ recorded significantly highest WCR followed by oxadiazon @ 0.4 kg a.i. ha⁻¹ and pendimethalin @ 1.5 kg a.i. ha⁻¹ as compared to weedy check at 45 and 60 DAS. The treatment metolachlor @ 1.0 kg a.i. ha⁻¹ registered significantly lowest values for WCR followed by metolachlor @ 1.5 kg a.i. ha⁻¹ and Alachlor @ 1.0 kg a.i. ha⁻¹. A similar trend was noticed at 90 DAS and at harvest wherein, the treatments Oxadiazon @ 0.5 kg a.i. ha⁻¹, Oxadiazon @ 0.4 kg a.i. ha⁻¹, Pendimethalin @ 1.5 kg a.i. ha⁻¹ registered significantly higher values for WCR. The lower

Table 6. Effect of herbicides on visual weed control rating (0-10scale) at different growth stages in onion

Treatments	30 DAS	45 DAS	60 DAS	90 DAS	At harvest
1. Alachlor (1.0 kg a.i/ha)	3.67	4.00	4.00	3.67	3.33
2. Alachlor (1.5 kg a.i/ha)	4.67	5.00	5.33	4.67	4.00
3. Oxyfluorfen (0.15 kg a.i/ha)	7.00	7.33	7.33	7.00	6.33
4. Oxyfluorfen (0.20 kg a.i/ha)	7.67	8.00	8.33	7.67	7.00
5. Pendimethalin (1.0 kg a.i/ha)	8.00	8.00	8.33	8.00	7.67
6. Pendimethalin (1.5 kg a.i/ha)	8.33	8.33	8.67	8.33	8.00
7. Oxadiazon (0.4 kg a.i/ha)	9.00	9.33	9.33	8.67	8.67
8. Oxadiazon (0.5 kg a.i/ha)	9.33	9.33	9.67	9.33	9.00
9. Metolachlor (1.0 kg a.i/ha)	3.00	3.00	3.33	3.00	2.67
10. Metolachlor (1.5 kg a.i/ha)	3.67	4.00	4.00	3.33	2.33
11. Weed free	3.33	9.33	9.67	9.33	9.00
12. Weedy check	0.00	0.00	0.00	0.00	0.00
S. Em ±	0.54	0.51	0.44	0.50	0.45
CD at 5%	1.58	1.50	1.29	1.47	1.33

WCR was found in metolachlor @ 1.5 kg a.i. ha⁻¹ followed by metolachlor @ 1.0 kg a.i. ha⁻¹ and alachlor @ 1.0 kg a.i. ha⁻¹.

4.1.3 Number of monocot weeds

The effect of herbicides and crop weed competition on the number of monocot weeds at different growth stages in onion indicated significant differences at all the stages studied (Table 7). In general, the number of monocot weeds increased from 30 days to harvest. At 30 DAS, the number of monocot weeds were highest in weedy check followed by metolachlor @ 1.0 kg a.i. ha⁻¹ and alachlor @ 1.0 kg a.i. ha⁻¹. While, significantly lowest number of monocot weeds were found in Oxadiazon @ 0.5 kg a.i. ha⁻¹ followed by Oxadiazon @ 0.4 kg a.i. ha⁻¹ and Oxyfluorfen @ 0.2 kg a.i. ha⁻¹.

It is interesting to note that 8 treatment controlled all the monocot weeds as compared to other treatments. At 60 DAS, the treatment Weedy check registered significantly higher number of monocot weeds which was followed by metolachlor @ 1.0 and 1.5 kg a.i. ha⁻¹. While, these values were found lowest in oxadiazon @ 0.5 kg a.i. ha⁻¹ followed by pendimethalin @ 1.5 kg a.i. ha⁻¹ and oxadiazon @ 0.4 kg a.i. ha⁻¹.

Similarly at 90 DAS, the treatment weedy check recorded significantly highest number of monocot weeds followed by Metolachlor @ 1.0 kg a.i. ha⁻¹ and Metolachlor @ 1.0 kg a.i. ha⁻¹. The number of monocot weeds were found to be lowest in Pendimethalin @ 1.5 kg a.i. ha⁻¹ followed by Oxadiazon @ 0.5 kg a.i. ha⁻¹ and oxadiazon @ 0.4 kg a.i. ha⁻¹.

At harvest stage also, a similar trend was observed for this trait and it was highest in weedy check followed by metolachlor @ 1.0 and 1.5 kg a.i. ha⁻¹. The treatment Oxadiazon @ 0.5 kg a.i. ha⁻¹ registered significantly lower

Table 7. Effect of herbicides and crop weed competition on number of monocot weeds at different growth stages in onion

Treatments	30 DAS	60 DAS	90 DAS	At harvest
1. Alachlor (1.0 kg a.i/ha)	3.31 (10.00)	3.33 (10.00)	3.59 (12.00)	4.02 (15.33)
2. Alachlor (1.5 kg a.i/ha)	2.64 (6.00)	3.03 (8.33)	3.35 (10.33)	3.81 (13.67)
3. Oxyfluorfen (0.15 kg a.i/ha)	2.82 (7.00)	2.82 (7.00)	3.16 (9.00)	3.59 (12.00)
4. Oxyfluorfen (0.20 kg a.i/ha)	1.90 (2.68)	2.44 (5.00)	2.88 (7.33)	3.16 (9.00)
5. Pendimethalin (1.0 kg a.i/ha)	1.99 (3.00)	1.99 (3.00)	2.44 (5.00)	2.82 (7.00)
6. Pendimethalin (1.5 kg a.i/ha)	1.99 (3.00)	1.71 (2.00)	2.23 (4.00)	2.63 (6.00)
7. Oxadiazon (0.4 kg a.i/ha)	1.05 (1.00)	1.91 (2.67)	2.36 (4.67)	2.74 (6.67)
8. Oxadiazon (0.5 kg a.i/ha)	0.00 (0.00)	1.71 (2.00)	2.33 (4.00)	2.39 (5.00)
9. Metolachlor (1.0 kg a.i/ha)	3.46 (11.00)	3.74 (13.00)	3.98 (15.00)	4.45 (18.00)
10. Metolachlor (1.5 kg a.i/ha)	3.16 (9.00)	3.46 (11.00)	3.73 (13.00)	4.23 (17.00)
11. Weed free	2.44 (5.00)	1.99 (3.00)	2.64 (6.00)	2.99 (8.00)
12. Weedy check	4.58 (20.00)	4.68 (21.00)	5.09 (25.00)	6.37 (39.67)
SEM ±	0.19	0.16	0.13	0.19
CD at 5%	0.56	0.48	0.39	0.56

Figures in parenthesis indicate actual values

values followed by pendimethalin @ 1.5 kg a.i. ha⁻¹ and oxadiazon @ 0.4 kg a.i. ha⁻¹ which were found to be on par with each other.

4.1.4 Number of dicot weeds

The data on the number of dicot weeds as influenced by herbicides at different growth stages indicated significant differences at all the growth stages (Table 8). The data indicated that irrespective of herbicide treatments, the number of dicot weeds increased from 30 DAS to harvest and the rate of increase was more in weedy check at later stages of crop growth and development. It was found that at all the stages (30, 60, 90 DAS and at harvest), the treatment weedy check registered significantly higher number of dicot weeds followed by metolachlor @ 1.0 and 1.5 kg a.i. ha⁻¹ which differed significantly among themselves. The number of dicot weeds were found to be significantly lower in oxadiazon @ 0.5 kg a.i. ha⁻¹ followed by oxadiazon @ 0.4 kg a.i. ha⁻¹ and pendimethalin @ 1.5 kg a.i. ha⁻¹ and these treatments differed significantly among themselves.

4.1.5 Total number of weeds

The effect of herbicides and crop weed competition on total number of weeds at different growth stages in onion indicated significant differences at all the stages studied (Table 9). The total number of weeds increase from 30 days to harvest stage.

At 30 DAS, the total number of weeds were highest in weedy check followed by metolachlor @ 1.0 kg a.i. ha⁻¹ and weed free check. While, significantly lowest total number of weeds were found in oxadiazon @ 0.5 kg a.i. ha⁻¹ followed by oxadiazon @ 0.4 kg a.i. ha⁻¹ and pendimethalin @ 1.5 kg a.i. ha⁻¹. It was found that at all the stages (60, 90 and at harvest) the

Table 8. Effect of herbicides and crop weed competition on number of dicot weeds at different growth stages in onion

Treatments	30 DAS	60 DAS	90 DAS	At harvest
1. Alachlor (1.0 kg a.i/ha)	3.44 (11.00)	3.72 (13.00)	4.11 (16.00)	4.46 (19.00)
2. Alachlor (1.5 kg a.i/ha)	3.13 (9.00)	3.44 (11.00)	3.86 (14.00)	4.23 (17.00)
3. Oxyfluorfen (0.15 kg a.i/ha)	2.75 (6.68)	3.09 (8.68)	3.54 (11.68)	4.00 (15.34)
4. Oxyfluorfen (0.20 kg a.i/ha)	2.56 (5.68)	2.92 (7.68)	3.40 (10.68)	3.81 (13.68)
5. Pendimethalin (1.0 kg a.i/ha)	2.64 (6.00)	2.99 (8.00)	3.46 (11.00)	3.87 (14.00)
6. Pendimethalin (1.5 kg a.i/ha)	2.44 (5.00)	2.82 (7.00)	3.31 (10.00)	3.74 (13.00)
7. Oxadiazon (0.4 kg a.i/ha)	2.09 (3.68)	2.55 (5.68)	2.93 (7.68)	3.19 (9.34)
8. Oxadiazon (0.5 kg a.i/ha)	1.79 (2.34)	2.30 (4.34)	2.70 (6.34)	2.82 (7.00)
9. Metolachlor (1.0 kg a.i/ha)	3.73 (13.00)	3.99 (15.00)	4.35 (18.00)	4.68 (21.00)
10. Metolachlor (1.5 kg a.i/ha)	3.46 (11.00)	3.74 (13.00)	4.11 (16.00)	4.58 (20.00)
11. Weed free	2.64 (6.00)	1.71 (2.00)	2.44 (5.00)	3.05 (8.34)
12. Weedy check	4.47 (19.00)	4.80 (22.00)	5.44 (28.68)	7.16 (50.34)
SEm ±	0.19	0.18	0.17	0.18
CD at 5%	0.56	0.55	0.49	0.55

Figures in parenthesis indicate actual values

Table 9. Effect of herbicides and crop weed competition on total number of weeds at different growth stages in onion

Treatments	30 DAS	60 DAS	90 DAS	At harvest
1. Alachlor (1.0 kg a.i/ha)	4.68 (21.00)	4.90 (23.00)	5.37 (28.00)	5.93 (34.34)
2. Alachlor (1.5 kg a.i/ha)	3.98 (15.00)	4.50 (19.34)	5.01 (24.34)	5.63 (30.67)
3. Oxyfluorfen (0.15 kg a.i/ha)	3.83 (13.67)	4.07 (15.67)	4.65 (20.67)	5.30 (27.34)
4. Oxyfluorfen (0.20 kg a.i/ha)	3.05 (8.34)	3.68 (12.67)	4.35 (18.00)	4.86 (22.67)
5. Pendimethalin (1.0 kg a.i/ha)	3.16 (9.00)	3.46 (11.00)	4.12 (16.00)	4.69 (21.00)
6. Pendimethalin (1.5 kg a.i/ha)	3.00 (8.00)	3.16 (9.00)	3.87 (14.00)	4.47 (19.00)
7. Oxadiazon (0.4 kg a.i/ha)	2.30 (4.67)	3.02 (8.34)	3.65 (12.34)	4.10 (16.00)
8. Oxadiazon (0.5 kg a.i/ha)	1.80 (2.34)	2.70 (6.34)	3.35 (10.34)	3.58 (12.00)
9. Metolachlor (1.0 kg a.i/ha)	5.00 (24.00)	5.38 (28.00)	5.82 (33.00)	6.32 (39.00)
10. Metolachlor (1.5 kg a.i/ha)	4.58 (20.00)	5.00 (24.00)	5.48 (29.00)	6.16 (37.00)
11. Weed free	3.45 (11.00)	2.45 (5.00)	3.45 (11.00)	4.16 (16.34)
12. Weedy check	6.32 (39.00)	6.66 (43.00)	7.14 (50.34)	9.54 (90.00)
SEm ±	0.21	0.17	0.20	0.22
CD at 5%	0.62	0.51	0.58	0.63

Figures in parenthesis indicate actual values

treatment weedy check registered significantly highest total number of weeds followed by metolachlor @ 1.0 and 1.5 kg a.i. ha⁻¹ which differed significantly among themselves. The total number of weeds were found significantly lowest in oxadiazon @ 0.5 kg a.i. ha⁻¹ followed by oxadiazon @ 0.4 kg a.i. ha⁻¹ and pendimethalin @ 1.5 kg a.i. ha⁻¹ and these treatments differed significantly among themselves.

4.1.6 Total dry weight of weeds

The total dry weight of weeds as influenced by different herbicides and crop weed competition at different growth stages in onion indicated significant differences at all the stages (Table 10). In general, the dry weight of weeds increased from 30 DAS to harvest. Irrespective of the stages, the dry weight of weeds was significantly higher in weedy check followed by metolachlor @ 1.0 and @ 1.5 kg a.i. ha⁻¹ and the treatment oxadiazon @ 0.5 kg a.i. ha⁻¹ registered significantly lower values followed by oxadiazon @ 0.4 kg a.i. ha⁻¹ and pendimethalin @ 1.0 kg a.i. ha⁻¹ which were found to be on par with each other at all the stages. The results indicated that the treatment oxadiazon @ 0.5 kg a.i. ha⁻¹ was most effective in reducing the total dry weight of weeds at all the stages.

4.1.7 Weed control efficiency

The data on weed control efficiency indicated significant differences due to various herbicides (Table 11). Among various herbicide treatments, WCE was found to be significantly higher in oxadiazon @ 0.5 kg a.i. ha⁻¹ (87.19) followed by oxadiazon @ 0.4 kg a.i. ha⁻¹ (85.71) pendimethalin @ 1.0 kg a.i. ha⁻¹ (84.24) and oxyfluorfen @ 0.15 kg a.i. ha⁻¹ (82.96) and these treatments were found to be on par with each other (Plate 1). However, the herbicide

Table 10. Effect of herbicides and crop weed competition on total dry weight (g/0.25 m² area) of weeds at different growth stages in onion

Treatments	30 DAS	60 DAS	90 DAS	At harvest
1. Alachlor (1.0 kg a.i/ha)	1.10 (12.05)	1.26 (17.60)	1.32 (20.59)	1.41 (25.38)
2. Alachlor (1.5 kg a.i/ha)	1.04 (10.33)	1.20 (15.33)	1.26 (18.03)	1.33 (21.00)
3. Oxyfluorfen (0.15 kg a.i/ha)	0.68 (4.10)	1.00 (9.33)	1.10 (12.30)	1.25 (17.29)
4. Oxyfluorfen (0.20 kg a.i/ha)	0.90 (7.33)	1.12 (12.33)	1.18 (15.00)	1.31 (20.04)
5. Pendimethalin (1.0 kg a.i/ha)	0.55 (3.00)	0.94 (8.00)	1.06 (11.00)	1.22 (16.00)
6. Pendimethalin (1.5 kg a.i/ha)	0.98 (8.61)	1.15 (13.61)	1.27 (18.06)	1.37 (23.10)
7. Oxadiazon (0.4 kg a.i/ha)	0.53 (2.56)	0.91 (7.56)	1.05 (10.49)	1.18 (14.50)
8. Oxadiazon (0.5 kg a.i/ha)	0.39 (2.03)	0.89 (7.00)	1.01 (10.00)	1.13 (12.99)
9. Metolachlor (1.0 kg a.i/ha)	1.23 (16.33)	1.34 (21.33)	1.39 (24.00)	1.52 (32.56)
10. Metolachlor (1.5 kg a.i/ha)	1.20 (15.00)	1.32 (20.00)	1.38 (23.29)	1.49 (30.18)
11. Weed free	0.45 (1.99)	0.28 (1.00)	0.65 (3.90)	0.85 (6.60)
12. Weedy check	1.30 (19.40)	1.71 (50.84)	1.95 (88.89)	2.01 (103.30)
SEm ±	0.08	0.05	0.07	0.06
CD at 5%	0.25	0.14	0.20	0.17

Figures in parenthesis indicate actual values



Plate 1: Effect of treatments on weed control efficiency in onion

Table 11. Effect of herbicides and crop weed competition on weed control efficiency (%) in onion

Treatments	Weed control efficiency (%)
1. Alachlor (1.0 kg a.i./ha)	75.00
2. Alachlor (1.5 kg a.i./ha)	79.28
3. Oxyfluorfen (0.15 kg a.i./ha)	82.96
4. Oxyfluorfen (0.20 kg a.i./ha)	80.25
5. Pendimethalin (1.0 kg a.i./ha)	84.24
6. Pendimethalin (1.5 kg a.i./ha)	77.24
7. Oxadiazon (0.4 kg a.i./ha)	85.71
8. Oxadiazon (0.5 kg a.i./ha)	87.19
9. Metolachlor (1.0 kg a.i./ha)	67.93
10. Metolachlor (1.5 kg a.i./ha)	70.27
11. Weed free	93.50
12. Weedy check	0.00
Sem \pm	1.49
CD at 5%	4.37

treatments metolachlor @ 1.0 kg a.i. ha⁻¹ registered the lowest values for WCE (67.93) followed by metolachlor @ 1.5 kg a.i. ha⁻¹ (70.27) and Alachlor @ 1.0 kg a.i. ha⁻¹ (75.00) and these treatments differed significantly among themselves.

4.2 Dry matter accumulation and its distribution

4.2.1 Leaf dry weight

The data on leaf dry weight at different growth stages in onion as influenced by herbicides and crop weed competition indicated significant differences at all stages except at 30 DAS (Table 12). In general, leaf dry weight increased upto 90 DAS and decreased thereafter.

At 60 DAS and 90 DAS, the leaf dry weight was significantly higher in weed free check followed by oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ and these treatments were on par with each other. The treatment weedy check recorded significantly lower leaf dry weight followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹ at both the stages (60 and 90 DAS).

The leaf dry weight was found significantly higher in oxyfluorfen @ 0.15 kg a.i. ha⁻¹ followed by weed free check and oxadiazon @ 0.5 kg a.i. ha⁻¹ at harvest. However, the treatments weedy check, metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹ registered significantly lower leaf dry weight as compared to other treatments.

4.2.2 Bulb dry weight

The effect of herbicides and crop weed competition on bulb dry weight at different growth stages in onion indicated significant differences due to

Table 12. Effect of herbicides and crop weed competition on dry matter accumulation of onion leaf (g plant⁻¹) at different growth stages

Sl. No.	Treatment	30 DAS	60 DAS	90 DAS	At harvest
1.	Alachlor (1.0 kg a.i/ha)	0.03	0.57	0.85	0.60
2.	Alachlor (1.5 kg a.i/ha)	0.03	0.55	0.82	0.58
3.	Oxyfluorfen (0.15 kg a.i/ha)	0.04	0.65	0.90	1.00
4.	Oxyfluorfen (0.20 kg a.i/ha)	0.04	0.68	0.92	0.70
5.	Pendimethalin (1.0 kg a.i/ha)	0.04	0.71	0.95	0.73
6.	Pendimethalin (1.5 kg a.i/ha)	0.04	0.60	0.88	0.65
7.	Oxadiazon (0.4 kg a.i/ha)	0.05	0.73	0.98	0.75
8.	Oxadiazon (0.5 kg a.i/ha)	0.05	0.75	1.00	0.80
9.	Metolachlor (1.0 kg a.i/ha)	0.03	0.53	0.80	0.55
10.	Metolachlor (1.5 kg a.i/ha)	0.03	0.50	0.73	0.53
11.	Weed free	0.03	0.80	1.10	0.90
12.	Weedy check	0.06	0.45	0.70	0.48
	SEm ±	0.018	0.031	0.069	0.019
	CD at 5%	NS	0.090	0.203	0.055

Table 13. Effect of herbicides and crop weed competition on dry matter accumulation in onion bulbs (g plant⁻¹) at different growth stages

Sl. No.	Treatment	30 DAS	60 DAS	90 DAS	At harvest
1.	Alachlor (1.0 kg a.i/ha)	0.016	0.28	2.89	3.58
2.	Alachlor (1.5 kg a.i/ha)	0.017	0.26	2.71	3.01
3.	Oxyfluorfen (0.15 kg a.i/ha)	0.029	0.39	3.45	4.11
4.	Oxyfluorfen (0.20 kg a.i/ha)	0.021	0.35	3.29	3.80
5.	Pendimethalin (1.0 kg a.i/ha)	0.032	0.41	3.68	4.91
6.	Pendimethalin (1.5 kg a.i/ha)	0.018	0.31	3.00	3.69
7.	Oxadiazon (0.4 kg a.i/ha)	0.038	0.51	3.80	5.28
8.	Oxadiazon (0.5 kg a.i/ha)	0.039	0.53	4.00	5.91
9.	Metolachlor (1.0 kg a.i/ha)	0.013	0.22	2.10	2.11
10.	Metolachlor (1.5 kg a.i/ha)	0.011	0.18	2.10	2.08
11.	Weed free	0.021	0.56	4.10	6.89
12.	Weedy check	0.004	0.11	1.70	1.80
	SEM ±	0.001	0.019	0.175	0.197
	CD at 5%	0.004	0.057	0.513	0.578



Plate 2: Effect of oxadiazon (0.5 kg ai/ha) on bulb yield in onion

treatments at all the stages (Table 13 and Plate 2). The bulb dry weight increased from 30 DAS to harvest and the per cent increase in bulb dry weight was more between 60 and 90 DAS as compared to other stages.

The bulb dry weight was found to be significantly higher in oxadiazon @ 0.5 kg a.i. ha⁻¹ followed by oxadiazon @ 0.4 kg a.i. ha⁻¹ and pendimethalin @ 1.0 kg a.i. ha⁻¹ at 30 DAS. While, this parameter was significantly lower in weedy check followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹.

At 60, 90 DAS and at harvest, the data followed a similar trend and the treatments weed free check registered significantly higher bulb dry weight followed by oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹. The treatment weedy check possessed significantly lower values for bulb dry matter followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹ as compared to other treatments.

4.2.3 Total dry matter

The data on total dry matter indicated that it increased from 30 DAS to harvest (Table 14). The per cent increase in TDM was found to be more between 60 and 90 DAS as compared to other stages.

At 30 DAS, the treatment oxadiazon @ 0.5 kg a.i. ha⁻¹ recorded significantly higher TDM followed by oxadiazon @ 0.4 kg a.i. ha⁻¹ and weed free check as compared to weedy check. The treatment weedy check registered significantly lower values for TDM followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹ indicating lower efficiencies of these herbicides.

The total dry matter was significantly higher in weed free check followed by oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ at all the stages studied (60, 90 DAS and at harvest). At these stages, the lowest TDM was found in treatment

Table 14. Effect of herbicides and crop weed competition on total dry matter accumulation (g plant⁻¹) at different growth stages in onion

Sl. No.	Treatment	30 DAS	60 DAS	90 DAS	At harvest
1.	Alachlor (1.0 kg a.i/ha)	0.046	0.850	3.740	4.437
2.	Alachlor (1.5 kg a.i/ha)	0.047	0.810	3.530	3.840
3.	Oxyfluorfen (0.15 kg a.i/ha)	0.069	1.040	4.350	5.363
4.	Oxyfluorfen (0.20 kg a.i/ha)	0.061	1.030	4.210	4.750
5.	Pendimethalin (1.0 kg a.i/ha)	0.077	1.120	4.630	5.890
6.	Pendimethalin (1.5 kg a.i/ha)	0.058	0.910	3.880	4.590
7.	Oxadiazon (0.4 kg a.i/ha)	0.088	1.240	4.780	6.280
8.	Oxadiazon (0.5 kg a.i/ha)	0.089	1.287	5.000	6.960
9.	Metolachlor (1.0 kg a.i/ha)	0.043	0.753	2.900	2.910
10.	Metolachlor (1.5 kg a.i/ha)	0.041	0.680	2.730	2.860
11.	Weed free	0.081	1.363	5.200	8.040
12.	Weedy check	0.024	0.560	2.400	2.530
	SEM ±	0.002	0.066	0.272	0.440
	CD at 5%	0.006	0.195	0.796	1.292

weedy check followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹ as compared to other treatments.

4.3 GROWTH PARAMETERS

4.3.1 Leaf area

The data on leaf area as influenced by herbicides and crop weed competition at different growth stages in onion indicated significant differences at all the stages studied (Table 15). The leaf area increased from 30 to 90 DAS and decreased thereafter towards maturity.

The leaf area was found to be significantly higher in weed free check followed by oxadiazon @ 0.4 and 0.5 kg a.i. ha⁻¹ as compared to other treatments and were on par with each other at 30 DAS. The treatment weedy check registered significantly lower leaf area followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹ which were on par with each other.

At 60 DAS, the treatment weed free check registered significantly higher leaf area followed by oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹, while the values were found to be significantly lower in weedy check followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹.

The leaf area was maximum at 90 DAS and the treatment weed free check showed significantly higher leaf area followed by oxyfluorfen @ 0.15 kg a.i. ha⁻¹ and oxadiazon @ 0.4 kg a.i. ha⁻¹. While, the leaf area was found to be the lowest in weedy check followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹.

At harvest, the leaf area was significantly higher in weed free check followed by oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹. However, the treatments

Table 15. Effect of herbicides and crop weed competition on leaf area (cm²/plant) at different growth stages in onion

Sl. No.	Treatment	30 DAS	60 DAS	90 DAS	At harvest
1.	Alachlor (1.0 kg a.i./ha)	13.07	158.20	340.10	72.10
2.	Alachlor (1.5 kg a.i./ha)	13.00	156.10	337.70	72.00
3.	Oxyfluorfen (0.15 kg a.i./ha)	13.60	168.10	352.50	76.33
4.	Oxyfluorfen (0.20 kg a.i./ha)	13.50	164.20	348.10	74.30
5.	Pendimethalin (1.0 kg a.i./ha)	13.80	169.10	349.10	77.10
6.	Pendimethalin (1.5 kg a.i./ha)	13.40	162.10	344.00	73.90
7.	Oxadiazon (0.4 kg a.i./ha)	14.20	171.20	351.40	78.10
8.	Oxadiazon (0.5 kg a.i./ha)	14.00	175.20	348.60	79.90
9.	Metolachlor (1.0 kg a.i./ha)	12.80	155.00	332.10	71.10
10.	Metolachlor (1.5 kg a.i./ha)	12.60	151.75	330.20	70.00
11.	Weed free	14.50	178.90	361.50	81.20
12.	Weedy check	12.00	149.20	310.00	63.10
	SEM ±	0.29	0.60	1.20	1.25
	CD at 5%	0.85	1.76	3.52	3.65

weedy check, metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹ recorded significantly lower leaf area and differed significantly among themselves.

4.3.2 Leaf area index

The effect of herbicides and crop weed competition on leaf area index (LAI) at different growth stages of onion indicated significant differences (Table 16). The LAI values increased from 30 DAS to 90 DAS and decreased thereafter. The data on LAI followed a similar trend as that of leaf area.

4.3.3. Absolute growth rate (AGR, g plant-1 day-1)

The absolute growth rate (AGR) indicated significant differences due to various treatments (Table 17) and in general, AGR values were less during 30-60 DAS and were more during later stages of crop growth (60-90 DAS).

At 30-60 DAS, the AGR was found to be significantly higher in weed free check followed by oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ while the values were the lowest in treatment weedy check followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹.

However, the AGR values at 60-90 DAS indicated that it was significantly higher in weed free check followed by oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹. The treatment metolachlor @ 1.0 kg a.i. ha⁻¹ registered significantly lower AGR followed by weedy check and metolachlor @ 1.5 kg a.i. ha⁻¹.

4.3.4 Relative growth rate (RGR, g g d-1)

The effect of herbicides and crop weed competition on relative growth rate (RGR) indicated significant differences due to treatments (Table 17). In general, RGR decreased towards later stages of crop growth.

Table 16. Effect of herbicides and crop weed competition on leaf area index (LAI) at different growth stages in onion

Sl. No.	Treatment	30 DAS	60 DAS	90 DAS	At harvest
1.	Alachlor 1.0 kg a.i/ha)	0.059	0.703	1.511	0.320
2.	Alachlor (1.5 kg a.i/ha)	0.058	0.717	1.501	0.320
3.	Oxyfluorfen (0.15 kg a.i/ha)	0.060	0.751	1.567	0.339
4.	Oxyfluorfen (0.20 kg a.i/ha)	0.060	0.730	1.551	0.330
5.	Pendimethalin (1.0 kg a.i/ha)	0.061	0.752	1.79	0.343
6.	Pendimethalin (1.5 kg a.i/ha)	0.060	0.720	1.530	0.328
7.	Oxadiazon (0.4 kg a.i/ha)	0.063	0.761	1.562	0.347
8.	Oxadiazon (0.5 kg a.i/ha)	0.062	0.779	1.549	0.355
9.	Metolachlor (1.0 kg a.i/ha)	0.057	0.689	1.476	0.316
10.	Metolachlor (1.5 kg a.i/ha)	0.056	0.675	1.467	0.311
11.	Weed free	0.064	0.795	1.607	0.361
12.	Weedy check	0.053	0.656	1.378	0.250
	SEM ±	0.002	0.025	0.040	0.011
	CD at 5%	0.005	0.074	0.118	0.032

Table 17. Effect of herbicides and crop weed competition on absolute growth rate (g plant⁻¹ day⁻¹) and relative growth rate (g g⁻¹ day⁻¹) different growth stages in onion

Sl. No.	Treatment	Absolute growth rate		Relative growth rate	
		30 - 60 DAS	60 - 90 DAS	30 - 60 DAS	60 - 90 DAS
1.	Alachlor (1.0 kg a.i/ha)	0.027	0.096	0.097	0.049
2.	Alachlor (1.5 kg a.i/ha)	0.025	0.091	0.095	0.049
3.	Oxyfluorfen (0.15 kg a.i/ha)	0.032	0.110	0.090	0.048
4.	Oxyfluorfen (0.20 kg a.i/ha)	0.032	0.106	0.094	0.047
5.	Pendimethalin (1.0 kg a.i/ha)	0.035	0.117	0.089	0.047
6.	Pendimethalin (1.5 kg a.i/ha)	0.028	0.102	0.092	0.048
7.	Oxadiazon (0.4 kg a.i/ha)	0.038	0.118	0.088	0.045
8.	Oxadiazon (0.5 kg a.i/ha)	0.040	0.124	0.089	0.045
9.	Metolachlor (1.0 kg a.i/ha)	0.024	0.024	0.095	0.045
10.	Metolachlor (1.5 kg a.i/ha)	0.021	0.068	0.094	0.046
11.	Weed free	0.043	0.128	0.094	0.045
12.	Weedy check	0.017	0.061	0.105	0.049
	SEm ±	0.002	0.004	0.003	0.002
	CD at 5%	0.007	0.013	0.008	NS

The RGR values during 30-60 DAS indicated that it was significantly higher in weedy check followed by metolachlor @ 1.0 and 1.5 kg a.i. ha⁻¹. The RGR values were found to be lower with oxadiazon @ 0.4 kg a.i. ha⁻¹ followed by oxadiazon @ 0.5 kg a.i. ha⁻¹ and oxyfluorfen @ 0.15 kg a.i. ha⁻¹ and were found to be on par with each other.

At 60-90 DAS, the treatments weedy check, alachlor @ 1.5 and 1.0 kg a.i. ha⁻¹ and oxyfluorfen @ 0.15 kg a.i. ha⁻¹ registered significantly higher RGR values as compared to other treatments. The RGR values were found to be significantly lower in metolachlor @ 1.0 kg a.i. ha⁻¹ and oxadiazon @ 0.5 kg a.i. ha⁻¹ and these treatments were on par with each other.

4.3.5 Crop growth rate (CGR, g m⁻² d⁻¹)

The data on CGR indicated significant differences due to various treatments at all the stages and it increased from 30 to 90 DAS (Table 18). The maximum CGR values were found in weed free check followed by oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹, while the values were found significantly lower in weedy check followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹ at 30 - 60 DAS.

At 60-90 DAS, the treatment weed free check registered significantly higher CGR followed by oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ over other treatments and were on par with each other. The CGR values were found to be lower in metolachlor @ 1.0 kg a.i. ha⁻¹ followed by weedy check and metolachlor @ 1.5 kg a.i. ha⁻¹.

Table 18. Effect of herbicides and crop weed competition on crop growth rate (g m⁻² day⁻¹) and net assimilation rate (mg cm⁻² day⁻¹) different growth stages in onion

Sl. No.	Treatment	Crop growth rate		Net assimilation rate	
		30 - 60 DAS	60 - 90 DAS	30 - 60 DAS	60 - 90 DAS
1.	Alachlor (1.0 kg a.i/ha)	1.20	4.27	0.54	0.78
2.	Alachlor (1.5 kg a.i/ha)	1.11	4.04	0.50	0.74
3.	Oxyfluorfen (0.15 kg a.i/ha)	1.42	4.89	0.56	0.86
4.	Oxyfluorfen (0.20 kg a.i/ha)	1.42	4.71	0.60	0.81
5.	Pendimethalin (1.0 kg a.i/ha)	1.54	5.20	0.60	0.92
6.	Pendimethalin (1.5 kg a.i/ha)	1.24	4.40	0.52	0.79
7.	Oxadiazon (0.4 kg a.i/ha)	1.69	5.24	0.64	1.41
8.	Oxadiazon (0.5 kg a.i/ha)	1.77	5.51	0.63	0.92
9.	Metolachlor (1.0 kg a.i/ha)	1.07	1.07	0.48	0.18
10.	Metolachlor (1.5 kg a.i/ha)	0.95	3.02	0.42	0.53
11.	Weed free	1.91	5.69	0.74	0.94
12.	Weedy check	0.76	2.71	0.36	0.55
	SEm ±	0.075	0.160	0.037	0.033
	CD at 5%	0.221	0.468	0.107	0.097

4.3.6 Net assimilation rate (NAR, mg cm⁻² day⁻¹)

The data on net assimilation rate indicated significant differences due to various herbicide treatments (Table 18). In general, the NAR values increased from 30-60 to 60-90 DAS.

At 30-60 DAS, NAR values were significantly higher in weed free check which was followed by oxadiazon @ 0.4 and 0.5 kg a.i. ha⁻¹ over other treatments. The NAR values were found to be significantly lower in weedy check followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹.

At 60-90 DAS, the treatments weed free check followed by oxadiazon @ 0.4 and 0.5 kg a.i. ha⁻¹ registered significantly higher values of NAR over other treatments. The NAR values were found to be lower in metolachlor @ 1.0 kg a.i. ha⁻¹ followed by metolachlor @ 1.5 kg a.i. ha⁻¹ and weedy check as compared to other treatments.

4.3.7 Specific leaf weight (SLW, mg/cm⁻²)

The data on SLW indicated significant differences due to various treatments at all the stages studied (Table 19). In general, SLW increased from 30 to 60 DAS and decreased thereafter. The SLW was significantly higher in weed free check followed by oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ at 30 DAS. However, significantly lower SLW was found in weedy check followed by alachlor @ 1.0 and 1.5 kg a.i. ha⁻¹.

At 60 DAS, the SLW was significantly higher in weed free check followed by oxadiazon @ 0.4 and 0.5 kg a.i. ha⁻¹. Whereas, the treatment weedy check registered significantly lower SLW followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹.

Table 19. Effect of herbicides and crop weed competition on specific leaf weight (mg cm^{-2}) at different growth stages in onion

Sl. No.	Treatment	30 DAS	60 DAS	90 DAS
1.	Alachlor (1.0 kg a.i./ha)	2.300	3.600	2.500
2.	Alachlor (1.5 kg a.i./ha)	2.310	3.520	2.430
3.	Oxyfluorfen (0.15 kg a.i./ha)	2.940	3.580	2.550
4.	Oxyfluorfen (0.20 kg a.i./ha)	2.960	4.140	2.640
5.	Pendimethalin (1.0 kg a.i./ha)	3.260	4.200	2.720
6.	Pendimethalin (1.5 kg a.i./ha)	2.990	3.700	2.560
7.	Oxadiazon (0.4 kg a.i./ha)	3.520	4.260	2.790
8.	Oxadiazon (0.5 kg a.i./ha)	3.570	4.280	2.790
9.	Metolachlor (1.0 kg a.i./ha)	2.340	3.410	2.410
10.	Metolachlor (1.5 kg a.i./ha)	2.380	3.290	2.210
11.	Weed free	4.140	4.470	3.040
12.	Weedy check	1.670	3.020	2.260
	SEM \pm	0.088	0.297	0.089
	CD at 5%	0.259	0.872	0.260

The treatment weed free check recorded significantly higher SLW followed by oxadiazon @ 0.5 kg a.i. ha⁻¹ and pendimethalin @ 1.0 kg a.i. ha⁻¹. The SLW was significantly lower in metolachlor @ 1.5 kg a.i. ha⁻¹, weedy check and metolachlor @ 1.0 kg a.i. ha⁻¹ and these treatments were on par with each other.

4.3.8 Leaf area ratio (LAR, cm² g⁻¹)

The leaf area ratio (LAR) indicated significant differences due to treatments at all the stages (Table 20). In general, LAR decreased from 30 DAS to harvest.

At all the stages (30, 60, 90 DAS and at harvest), the LAR values were significantly higher in the treatment weedy check followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹ as compared to other treatments. However, the treatment weed free check recorded significantly lower LAR values followed by oxadiazon @ 0.4 and 0.5 kg a.i. ha⁻¹ as compared to other treatments.

4.3.9 Leaf area duration (LAD, days)

The data on leaf area duration (LAD) indicated significant differences due to treatments at all the stages (Table 21). In general, LAD values increased from 30 to 90 DAS and decreased thereafter.

During both 30-60 and 60-90 DAS, the treatments weed free check, oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ registered significantly higher values for LAD. The treatment weedy check and metolachlor @ 1.5 kg a.i. ha⁻¹ recorded significantly lower values for LAD at both the stages.

The LAD values were found to be significantly higher in oxadiazon @ 0.5 kg a.i. ha⁻¹ followed by weed free check and oxadiazon @ 0.4 kg a.i.

Table 20. Effect of herbicides and crop weed competition on leaf area ratio ($\text{cm}^2 \text{g}^{-1}$) at different growth stages in onion

Sl. No.	Treatment	30 DAS	60 DAS	90 DAS	At harvest
1.	Alachlor (1.0 kg a.i/ha)	284.13	186.12	90.94	16.25
2.	Alachlor (1.5 kg a.i/ha)	276.60	192.72	95.67	18.75
3.	Oxyfluorfen (0.15 kg a.i/ha)	197.10	162.40	81.03	14.23
4.	Oxyfluorfen (0.20 kg a.i/ha)	221.31	159.42	82.68	15.64
5.	Pendimethalin (1.0 kg a.i/ha)	179.22	150.98	75.42	13.09
6.	Pendimethalin (1.5 kg a.i/ha)	231.03	178.13	88.66	16.10
7.	Oxadiazon (0.4 kg a.i/ha)	161.36	138.06	73.52	12.44
8.	Oxadiazon (0.5 kg a.i/ha)	157.30	136.13	71.12	11.48
9.	Metolachlor (1.0 kg a.i/ha)	297.67	205.84	114.52	24.43
10.	Metolachlor (1.5 kg a.i/ha)	307.32	223.16	120.95	24.48
11.	Weed free	18.01	131.25	69.52	10.10
12.	Weedy check	500.00	266.00	129.17	24.94
	SEM \pm	8.195	10.375	7.939	1.611
	CD at 5%	26.145	304.26	23.280	4.726

Table 21. Effect of herbicides and crop weed competition on leaf area duration (days) at different growth stages in onion

Sl. No.	Treatment	30 - 60 DAS	60 - 90 DAS	90 - 120 DAS
1.	Alachlor (1.0 kg a.i/ha)	11.43	33.21	27.47
2.	Alachlor (1.5 kg a.i/ha)	11.63	33.27	27.32
3.	Oxyfluorfen (0.15 kg a.i/ha)	12.17	34.58	28.40
4.	Oxyfluorfen (0.20 kg a.i/ha)	11.85	34.16	28.16
5.	Pendimethalin (1.0 kg a.i/ha)	12.20	34.96	28.83
6.	Pendimethalin (1.5 kg a.i/ha)	11.70	33.75	27.87
7.	Oxadiazon (0.4 kg a.i/ha)	12.36	34.85	28.64
8.	Oxadiazon (0.5 kg a.i/ha)	12.62	35.60	29.64
9.	Metolachlor (1.0 kg a.i/ha)	11.19	32.48	26.88
10.	Metolachlor (1.5 kg a.i/ha)	10.97	33.15	27.69
11.	Weed free	12.89	36.03	29.52
12.	Weedy check	10.64	30.51	24.87
	SEM ±	0.424	0.847	0.713
	CD at 5%	1.244	2.485	2.090

ha⁻¹ at 90-120 DAS. Whereas, significantly lower LAD values were noticed in weedy check followed by metolachlor @ 1.0 kg a.i. ha⁻¹ and alachlor @ 1.5 kg a.i. ha⁻¹.

4.3.10 Biomass duration (BMD, g days)

The data on biomass duration (BMD) as influenced by herbicides and crop weed competition presented in Table 22 indicated significant differences due to various treatments and it increased from 30 - 120 DAS.

At all the stages (30-60, 60-90 and 90-120 DAS) the BMD values were found to be significantly higher in weed free check followed by oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹, whereas the treatment, weedy check registered significantly lower values for BMD followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹ as compared to other treatments.

4.3.11 Specific leaf area (SLA, cm²/mg)

The effect of herbicides and crop weed competition on specific leaf area (SLA) indicated significant differences due to treatments at all the stages (Table 23). In general, SLA decreased from 30 DAS to 60 DAS and increased thereafter.

The SLA was significantly higher in weedy check followed by alachlor @ 1.0 and 1.5 kg a.i. ha⁻¹. The treatment weed free check registered significantly lower SLA values followed by oxadiazon @ 0.5 kg a.i. ha⁻¹ and pendimethalin @ 1.0 kg a.i. ha⁻¹ as compared to other treatments.

At 60 DAS, the treatments weedy check, metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹ recorded significantly higher SLA vales, while the treatments weed

Table 22. Effect of herbicides and crop weed competition on biomass duration (g days) at different growth stages in onion

Sl. No.	Treatment	30 - 60 DAS	60 - 90 DAS	90 - 120 DAS
1.	Alachlor (1.0 kg a.i/ha)	13.44	68.85	122.66
2.	Alachlor (1.5 kg a.i/ha)	12.86	65.10	110.55
3.	Oxyfluorfen (0.15 kg a.i/ha)	16.64	80.85	145.70
4.	Oxyfluorfen (0.20 kg a.i/ha)	16.37	78.60	134.40
5.	Pendimethalin (1.0 kg a.i/ha)	17.96	86.25	157.80
6.	Pendimethalin (1.5 kg a.i/ha)	14.52	71.85	127.05
7.	Oxadiazon (0.4 kg a.i/ha)	19.92	90.27	165.90
8.	Oxadiazon (0.5 kg a.i/ha)	20.64	94.31	179.40
9.	Metolachlor (1.0 kg a.i/ha)	11.94	54.80	87.15
10.	Metolachlor (1.5 kg a.i/ha)	10.80	51.15	83.85
11.	Weed free	21.66	98.45	198.60
12.	Weedy check	8.76	44.40	73.95
	SEM ±	0.458	3.407	6.492
	CD at 5%	1.344	9.990	19.038

Table 23. Effect of herbicides and crop weed competition on specific leaf area ($\text{cm}^2 \text{mg}^{-1}$) at different growth stages in onion

Sl. No.	Treatment	30 DAS	60 DAS	90 DAS
1.	Alachlor (1.0 kg a.i./ha)	0.44	0.27	0.40
2.	Alachlor (1.5 kg a.i./ha)	0.43	0.28	0.41
3.	Oxyfluorfen (0.15 kg a.i./ha)	0.34	0.26	0.39
4.	Oxyfluorfen (0.20 kg a.i./ha)	0.34	0.24	0.38
5.	Pendimethalin (1.0 kg a.i./ha)	0.31	0.24	0.37
6.	Pendimethalin (1.5 kg a.i./ha)	0.33	0.27	0.39
7.	Oxadiazon (0.4 kg a.i./ha)	0.28	0.23	0.36
8.	Oxadiazon (0.5 kg a.i./ha)	0.28	0.23	0.36
9.	Metolachlor (1.0 kg a.i./ha)	0.43	0.29	0.41
10.	Metolachlor (1.5 kg a.i./ha)	0.42	0.30	0.45
11.	Weed free	0.24	0.22	0.33
12.	Weedy check	0.60	0.33	0.44
	SEM \pm	0.011	0.010	0.011
	CD at 5%	0.033	0.030	0.033

free check, oxadiazon @ 0.5 kg a.i. ha⁻¹ and pendimethalin @ 1.0 kg a.i. ha⁻¹ possessed significantly lower values for SLA.

The SLA was found to be maximum in metolachlor @ 1.5 kg a.i. ha⁻¹ followed by weedy check and metolachlor @ 1.0 kg a.i. ha⁻¹, while SLA values were significantly low in weed free check, oxadiazon @ 0.5 kg a.i. ha⁻¹ and pendimethalin @ 1.0 kg a.i. ha⁻¹ as compared to other treatments.

4.4 BULB YIELD

The data on bulb yield indicated significant differences due to treatments (Table 24). The bulb yield was significantly higher in weed free check followed by oxadiazon @ 0.5 kg a.i. ha⁻¹, oxadiazon @ 0.4 kg a.i. ha⁻¹, pendimethalin @ 1.0 kg a.i. ha⁻¹, oxyfluorfen @ 0.15 and 0.2 kg a.i. ha⁻¹. However, the lowest bulb yield was recorded in weedy check which was followed by metolachlor @ 1.0 and 1.5 kg a.i. ha⁻¹ and alachlor @ 1.5 kg a.i. ha⁻¹ as compared to other treatments.

4.5 WEED INDEX (%)

The data on weed index (WI) as influenced by herbicides and crop weed competition indicated significant differences due to treatments (Table 24). The lowest weed index values were found in weed free check followed by oxadiazon @ 0.5 kg a.i. ha⁻¹, oxadiazon @ 0.4 kg a.i. ha⁻¹ and pendimethalin @ 1.0 kg a.i. ha⁻¹. The WI values were found to be significantly

Table 24. Effect of herbicides and crop weed competition on fresh bulb yield ($q\ ha^{-1}$) and weed index (%) in onion

Sl. No.	Treatment	Fresh bulb yield ($q\ ha^{-1}$)	Weed index (%)
1.	Alachlor (1.0 kg a.i/ha)	126.41	39.61
2.	Alachlor (1.5 kg a.i/ha)	111.46	46.33
3.	Oxyfluorfen (0.15 kg a.i/ha)	161.38	22.54
4.	Oxyfluorfen (0.20 kg a.i/ha)	158.95	23.55
5.	Pendimethalin (1.0 kg a.i/ha)	170.36	18.10
6.	Pendimethalin (1.5 kg a.i/ha)	150.01	28.06
7.	Oxadiazon (0.4 kg a.i/ha)	189.11	9.07
8.	Oxadiazon (0.5 kg a.i/ha)	191.89	8.45
9.	Metolachlor (1.0 kg a.i/ha)	95.89	53.87
10.	Metolachlor (1.5 kg a.i/ha)	99.19	52.34
11.	Weed free	209.60	0.00
12.	Weedy check	49.00	76.60
	SEm \pm	4.42	1.97
	CD at 5%	12.95	5.76

higher in weedy check followed by metolachlor @ 1.0 and 1.5 kg a.i. ha⁻¹ as compared to other treatments.

4.6 BIOCHEMICAL PARAMETERS

4.6.1 Total chlorophyll content (mg g fresh wt⁻¹)

The data on total chlorophyll content as influenced by herbicides and crop weed competition indicated significant differences at both the stages (Table 25). In general, chlorophyll content increased from 30 to 90 DAS.

The treatments weed free check registered significantly higher total chlorophyll content followed by oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ at both the stages. However, the total chlorophyll content was significantly lower in weedy check followed by metolachlor @ 1.5 and 1.0 kg a.i. ha⁻¹ as compared to other treatments.

4.7 ECONOMICS

The data on economics of various herbicides and crop weed competition are presented in Table 26. Among the various herbicide treatments, the application of oxadiazon @ 0.4 kg a.i. ha⁻¹ recorded the maximum benefit : cost ratio (1:14.08) followed by oxadiazon @ 0.5 kg a.i. ha⁻¹ (1:13.93). However, the application of metalachor @ 1.5 kg ai ha⁻¹ recorded lesser B:C ratio (1:5.99). The weed free check recorded the highest B:C ratio (1:14.32) as compared to other treatments.

Table 25: Effect of herbicides and crop weed competition on total chlorophyll content (mg g⁻¹ fr. wt.) at different growth stages in onion

Sl. No.	Treatment	30 DAS	90 DAS
1.	Alachlor (1.0 kg a.i./ha)	0.29	0.43
2.	Alachlor (1.5 kg a.i./ha)	0.24	0.40
3.	Oxyfluorfen (0.15 kg a.i./ha)	0.34	0.48
4.	Oxyfluorfen (0.20 kg a.i./ha)	0.33	0.47
5.	Pendimethalin (1.0 kg a.i./ha)	0.35	0.50
6.	Pendimethalin (1.5 kg a.i./ha)	0.31	0.45
7.	Oxadiazon (0.4 kg a.i./ha)	0.36	0.51
8.	Oxadiazon (0.5 kg a.i./ha)	0.37	0.53
9.	Metolachlor (1.0 kg a.i./ha)	0.22	0.37
10.	Metolachlor (1.5 kg a.i./ha)	0.21	0.36
11.	Weed free	0.40	0.55
12.	Weedy check	0.19	0.34
	SEm ±	0.019	0.020
	CD at 5%	0.056	0.059

Table 26. Economics of weed management practices

Sl. No.	Treatment	Yield (q/ha)	Gross return (Rs./ha)	Cost of cultivation (Rs./ha)	Net return (Rs./ha)	B :C ratio
1.	Alachlor (1.0 kg a.i/ha)	126.41	63205	6170	57035	9.24
2.	Alachlor (1.5 kg a.i/ha)	111.46	55730	6430	79300	7.66
3.	Oxyfluorfen (0.15 kg a.i/ha)	161.38	80690	680	73840	10.77
4.	Oxyfluorfen (0.20 kg a.i/ha)	158.95	79475	7250	72225	9.96
5.	Pendimethalin (1.0 kg a.i/ha)	170.36	85180	7250	77930	10.74
6.	Pendimethalin (1.5 kg a.i/ha)	150.01	75005	8050	66955	8.31
7.	Oxadiazon (0.4 kg a.i/ha)	189.11	94555	6270	88285	14.08
8.	Oxadiazon (0.5 kg a.i/ha)	191.89	95945	6425	89520	13.93
9.	Metolachlor (1.0 kg a.i/ha)	95.89	47945	6610	41335	6.25
10.	Metolachlor (1.5 kg a.i/ha)	99.19	49595	7090	42505	5.99
11.	Weed free	209.60	104800	6850	98150	14.32
12.	Weedy check	49.00	24500	5400	19050	3.49

1. Basic cost of cultivation = Rs. 6650/ha 2. Price of onion = Rs. 400/q

3. Cost of herbicides

a) Alachlor 50EC = Rs. 260/l

b) Oxyfluorfen 23.5 EC = Rs. 1880/l

c) Pendimethalin 30EC = Rs. 480/l

d) Oxadiazon 48EC = Rs. 740/l

e) Metolachlor 50 EC = Rs. 480/l

DISCUSSION

V. DISCUSSION

Onion is one of the most important commercial vegetable spice crops of India. Among many biotic factors, the competition with weeds cause considerable reduction in the yield potential. It has been estimated that the extent of reduction in yield potential ranges from 48 to 85 per cent depending on the duration of the crop-weed competition and the intensity of weeds. Hence, a field experiment was conducted to study the influence of herbicides and crop-weed competition in direct seeded onion at Main Research Station, Dharwad during *kharif* 1999. An attempt has been made to reason out the differential behaviour of various herbicides and the effect of crop-weed competition on morphological, growth, physiological parameters and yield potential in onion.

5.1 WEED FLORA

The important monocotyledonous weeds observed in the experimental area were *Cynodon dactylon*, *Dinebra retroflexa* and *Cyperus rotundus*. While, the common dicotyledonous weeds noticed were *Abutilon indicum*, *Acanthospermum hispidum*, *Ageratum conyzoides*, *Alternanthera sessilis*, *Amaranthus viridis*, *Boreria sp.*, *Cynotis cristata*, *Commelina benghalensis*, *Desmodium diffusum*, *Digeria arvensis*, *Euphorbia sp.*, *Lagasca mollis*, *Phyllanthus niruri*, *Physalis minima*, *Portulaca oleraceae*, *Trichoderma indicum*. Murthy (1950) observed 57 weed species in the black cotton soils of Dharwad. Krishnamurthy (1957) listed as many as 203 weed species that are commonly found on cultivated fields of Karnataka.

5.2 Phytotoxicity ratings

In the present study, it was observed that the treatment with Oxyfloufen @ 0.2 kg a.i. ha⁻¹ and Pendimethalin @ 1.5 kg a.i. ha⁻¹ registered significantly higher phytotoxic effects as compared to other herbicides and the least phytotoxicity was found with the herbicide oxadiazon at both the concentrations this indicates that oxadiazon possesses least phytotoxic rating and is well suited for weed control in onion. The phytotoxic effects were more pronounced during early stages and the values declined at later stages of crop development, which may be attributed to microbial decomposition and the detoxification of herbicides. Thus, it is clear that the use of oxadiazon causes minimum damage during early stages of the crop and is an effective herbicide for the management of weeds in onion.

The data on weed control ratings indicated that the treatments Oxadiazon @ 0.5 kg a.i. ha⁻¹, Oxadiazon @ 0.4 kg a.i. ha⁻¹ and Pendimethalin @ 1.5 kg a.i. ha⁻¹ registered significantly higher values indicating the superiority of these herbicides over others. However, the application of Metolachlor @ 1.0 and 1.5 kg a.i. ha⁻¹ were found ineffective for weed control rating at all the stages. The present study revealed that only some herbicides are promising as compared to others. However in weedy check treatment, there was a profuse growth of weeds throughout the crop growth period resulting in the suppression of growth and yield of onion. Similarly, Hanumantharaju (1992) also showed that oxadiazon was more effective in onion and resulted in higher weed control ratings as compared to other herbicides.

The number of weeds (monocot, dicot and total) increased from 30 days to harvest and the weedy check treatment possessed significantly higher

number of weed population at all the stages studied. Among the herbicides, Oxadiazon 0.5 and 0.4 kg ai/ha significantly reduced the monocot, dicot and total number of weeds at all the stages studied and thus indicated its effectiveness in controlling weeds. However, metolachlor was not effective in controlling both monocot and dicot weeds. These results are in conformity with the findings of Jaswinder Singh *et al.* (1991), Nadagouda (1995) and Nekar (1997).

Murthy (1982) and Bhanumurthy and Subramanian (1989) opined that weed dry matter is a better parameter to measure the competition than the weed number. In the present study, the weed dry matter increase from 30 DAS to harvest. The treatment weedy check recorded significantly higher weed dry matter at all the stages. Among various herbicides, oxadiazon was found to be very effective in reducing the dry matter of the weeds significantly at all the stages while, metolachlor was least effective. Similarly, several workers have reported the effectiveness of oxadiazon in reducing the dry matter of weeds in onion (Bhan *et al.*, 1976; Bhalla, 1978; Patel *et al.*, 1987 and Pandey *et al.*, 1990).

The weed control efficiency was significantly higher with Oxadiazon @ 0.5 kg a.i. ha⁻¹, Oxadiazon @ 0.4 kg a.i. ha⁻¹, Oxyfluofen @ 0.2 kg a.i. ha⁻¹ and Oxyfluofen @ 0.15 a.i. kg ha⁻¹ while, it was less with Metolachlor @ 1.0 kg a.i. ha⁻¹, Metolachlor @ 1.5 kg a.i. ha⁻¹ and Alachlor @ 1.0 kg a.i. ha⁻¹. However, the application of metolachlor was found ineffective and resulted in lesser weed control efficiency values. Similar results have been reported by Patel *et al.* (1986), Mishra *et al.* (1986) and Phogat *et al.* (1989).

5.3 EFFECT OF HERBICIDES AND CROP-WEED COMPETITION ON GROWTH PARAMETERS

The leaf and bulb dry weight were found to be significantly higher with weed free treatment which was followed by treatments with oxadiazon. The leaf dry weight increased upto 90 DAS and decreased thereafter due to leaf senescence. While, the bulb dry weight increased continuously from 30 DAS to harvest. The data clearly shows that the crop weed competition decreases both leaf and bulb dry matter and these parameters were significantly higher with the application of oxadiazon.

Leaf area and leaf area index (LAI) increased upto 90 DAS and decreased at later stages due to leaf senescence. Bhan *et al.*, (1976) also reported the occurrence of leaf senescence after 90 days in onion. Light and temperature affect the growth and development. The LAI was maximum in weed free check and weedy check recorded significantly lower values for leaf area and leaf area index (LAI). Among the herbicides, the application of oxadiazone resulted in higher values for leaf area and leaf area index (LAI) at all the stages. However, the application of metachlor was less effective in controlling weeds and resulted in lower values for leaf area and leaf area index. Similarly, Manjunath *et al.* (1989) also observed differential effect of herbicides on leaf area development in onion. The present investigation clearly indicated that oxadiazone effectively controls the weeds at all the stages and thus helps the onion plant to grow better with higher leaf expansion rates finally resulting in higher values for leaf area index.

The amount of dry matter produced is an indication of the overall utilization of resources and better light interception. Total dry matter increased from 30 days to harvest. The weed free treatment recorded significantly higher

total dry matter during 60, 90 and harvest stages and the TDM was found to be the lowest in weedy check. This suggests that weed competition affects various morphological traits and finally reduce the total dry matter production.

Among various herbicides tested, oxadiazon was found very effective in controlling the weeds and resulted in significantly higher total dry matter production by onion. Similarly, Patel *et al.* (1986) Shah and Patel (1995) and Nadagoud (1995) opined that among the various herbicides, the application of oxadiazon was found very effective in onion and resulted in increased growth components and total dry matter production in onion.

In the present study, it was noticed that metolachlor was least effective in controlling the weeds in onion and hence resulted in lower TDM production by onion. This herbicide was not found to be beneficial for onion. Hicks and Wehtje (1986) have also reported that Metolachlor caused crop injury in onion when applied at higher concentrations and recorded significantly lower yield than pendimethalin.

The absolute growth rate refers to dry weight increase per unit time. AGR values increased from 60-90 DAS and at both the stages (30-60 and 60-90 DAS), the weed free treatment had significantly higher AGR values and it was found to be lowest in weedy check. This clearly indicates that the efficiency of the plant in terms of dry matter production is hindered due to weed competition. Among the herbicides, the application of Oxadiazon was found beneficial and resulted in significantly higher values for AGR. Similarly, Govindra Singh *et al.* (1985) and Porwal and Singh (1993) also showed that oxadiazon was effective in onion and resulted in increased growth components due to reduced weed competition.

The leaf area ratio indicates the size of assimilatory surface area in relation to total dry matter the LAR was more during early stage and decreased towards maturity. Brewster (1979) also indicated that in onion LAR decreased towards maturity. It was significantly higher in weedy check and was lowest in weed free check. The increased LAR due to weed competition suggests that there is a tendency to produce more leaf area per unit dry matter for better light interception under competition with weeds. Among the herbicides, oxadiazon recorded lower LAR. Manjunath *et al.* (1989) also reported that depending on the herbicides, there was variation in growth parameters.

The leaf area duration (LAD) is the total amount of leaf area present over a particular period of growth. LAD is an important growth parameter that influences competition. It increased from 30-90 days and decreased thereafter due to leaf senescence. LAD values were highest in weed free treatment followed by the application of oxadiazon. The application of metolachlor at the rate 1.5 kg ai/ha and weedy check possessed significantly lower values for LAD.

The improvement of LAD values particularly at later phases of crop development is beneficial. The use of oxadiazone was found very effective in increasing the LAD values particularly at later phases of crop development which subsequently resulted in higher bulb yield. Manjunath *et al.* (1989) indicated that the presence of weeds resulted in significant decrease of LAD values. Thus any attempt to increase the LAD values through the use of appropriate herbicide is a rewarding exercise.

Biomass duration (BMD) indicates the maintenance of dry matter over a period of time and is essential for prolonged supply of photosynthates to the developing sinks. The biomass duration increased with the age of the crop upto

120 DAS. The weed free treatment recorded significantly higher BMD values at all the stages studied and it was found to be lowest with weedy check. This suggest that crop-weed competition results in decreased TDM, leaf area index (LAI), leaf area duration, CGR, NAR, SLW and finally results in decreased BMD. Among the herbicides, the higher BMD values were found with oxadiazon treatment indicating the superiority of this herbicide in onion. Patel *et al.* (1986) also reported that oxadiazone was very effective in onion.

Crop growth rate (CGR) is influenced by LAI, photosynthetic rate and leaf angle and is an index of the amount of light intercepted. Whereas, net assimilation rate (NAR) shows the growth rate per unit leaf area i.e., assimilatory surface. NAR decreased as growth advanced mainly due to shading and senescence. The specific leaf weight (SLW) is an index of leaf thickness and it increased from 30-60 DAS and decreased thereafter due to senescence of leaves. The values for CGR, NAR and SLW were found highest with weed free treatment and these values were lowest in weedy check.

Among the herbicides, application of oxadiazon was very effective and resulted in significantly higher values for CGR, NAR and SLW. This data clearly indicates that the growth parameters are very much influenced by crop-weed competition and herbicides improve these growth parameters. Govindra Singh *et al.* (1985) also reported an increase in growth attributes with the use of oxadiazon in onion.

The specific leaf area (SLA) was found more with weedy check and was less with weed free treatment. Different herbicides had differential impact on SLA.

The loss in bulb yield depends upon the density of weeds, duration of weeds, type of weed species present and competing ability of crops. Babiker *et al.* (1987) noticed that unrestricted growth reduced the crop yield by 98 per cent and onion was most sensitive to weed competition between the second and six weeks after crop emergence. The present study indicated that the bulb yield was highest in weed free treatment and was found lowest in weedy check treatment. The crop weed competition resulted in 76.68 per cent reduction in bulb yield. Similarly, the yield reduction of as higher as 78.1 per cent in seeded onion was reported by Western *et al.* (1990). Among the herbicides, the application of Oxadiazon @ 0.50 kg ai/ha was found superior followed by Oxadiazon 0.40 kg ai/ha, Pendimethalin 1.00 kg ai/ha, Oxyfluorfen 0.15 kg ai/ha and Oxyflourfen 0.20 kg/ha. However, the application of metolachlor @ 1.00 and 1.50 kg ai/ha was not effective as compared to other herbicides. Patel *et al.*, (1986) also reported that the application of oxadiazone @ 0.5 kg ai/ha was fond effective in reducing weed dry weight and increased bulb dry matter and bulb yield significantly.

The weed index (WI) is the reduction in crop yield due to the presence of weeds in comparison with weed free plot expressed as percentage. The weed index (WI) values were found highest in weedy check (76.6%) followed by the application of metolachlor 1.0 kg ai/ha (53.87%) and metolachlor 1.5 kg ai/ha (52.34). Among the herbicides, the application oxadiazon resulted in significantly lower values for weed index (<9.1%). This clearly indicates that the herbicide oxadiazone was very effective in controlling weeds and thus resulted in significantly lower values for weed index. The effectiveness of herbicides can best be judged based on weed index values. Porwal and Singh

(1993) reported that oxadiazon was more effective in onion and resulted in significantly lower values of WI.

5.5 BIOCHEMICAL PARAMETERS

The total chlorophyll content increased from 30-90 DAS and weed free treatment possessed higher values for total chlorophyll content. The treatment weedy check recorded significantly lower values for this trait. The application of oxadiazon resulted in significant increase of total chlorophyll content while, the application of metolachlor was phytotoxic and resulted in decreased values for total chlorophyll content. Thus, it is inferred that oxadiazon is the best herbicide for onion which not only improves morpho-physiological traits but also the biochemical component i.e. total chlorophyll content. Hicks and Wehtje (1986) reported that application of higher rate of metolachlor caused crop injury and decreased total chlorophyll content in leaves.

The benefit : cost ratio indicated that among the herbicides, oxadiazon @ 0.4 kg ai/ha recorded the highest benefit : cost ratio (14.08) followed by oxadiazon 0.5 kg ai/ha (13.93). The benefit : cost ratio was very less with the application of metolachlor (<6.30).

5.6 FUTURE LINE OF WORK

- 1) The effect of herbicides on various biochemical constituents and biophysical parameters may be assessed.
- 2) The genotypic variability may be tested for various herbicides.
- 3) The effect of herbicides on quality parameters may be assessed to understand the basic mechanisms involved in biosynthetic pathways.
- 4) Use of radio active herbicides to understand the mode of action of different herbicides in relation to physiological parameters may be assessed.

SUMMARY

VI. SUMMARY

A field experiment was conducted at Main Research Station, University of Agricultural Sciences, Dharwad during *kharif* 1999 to study the influence of herbicides and crop weed competition on weed control efficiency in onion. The experiment was laid out in randomized block design with one genotype (*Nasik Red*) and five herbicides at two concentrations (Alachlor @ 1.0 kg a.i. ha⁻¹ and 1.5 kg a.i. ha⁻¹, oxyfluorfen @ 0.15 kg a.i. ha⁻¹ and 0.20 kg a.i. ha⁻¹, oxadiazon @ 0.4 kg a.i. ha⁻¹ and 0.5 kg a.i. ha⁻¹, Metolachlor @ 1.0 kg a.i. ha⁻¹ and 1.5 kg a.i. ha⁻¹ and pendimethalin @ 1.0 kg a.i. ha⁻¹ and 1.5 kg a.i. ha⁻¹). The results obtained are summarized in this chapter.

1. The phytotoxic ratings were more during early stages and decreased at later stages. The application of oxyfluorfen @ 0.20 kg a.i. ha⁻¹ was found to be phytotoxic during early stages. The herbicide oxadiazon at both @ 0.4 and 0.5 kg a.i. ha⁻¹ was not phytotoxic to the crop.
2. The application of oxadiazon @ 0.4 and 0.5 kg a.i. ha⁻¹ resulted in higher weed control ratings at all the stages and the herbicide metolachlor is less effective.
3. The number of monocot weeds, dicot weeds and total number of weeds were found to be maximum in weedy check and the herbicide treatments oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ and pendimethalin @ 1.5 kg a.i. ha⁻¹ decreased these parameters to a greater extent. All these parameters increased from 30 DAS to harvest.
4. The total dry weight of weeds was found to be significantly higher in weedy check and the application of oxadiazon @ 0.5 kg and 0.4 kg a.i. ha⁻¹ significantly decreased the weed dry matter. The weed control

efficiency was the highest with oxadiazon @ 0.5 kg a.i. ha⁻¹ followed by oxadiazon @ 0.4 kg a.i. ha⁻¹ and pendimethalin @ 1.0 kg a.i. ha⁻¹.

5. The important morpho-physiological traits *viz.*, leaf dry weight, bulb dry weight and total dry weight were found higher in weed free treatment and these parameters were the lowest in weedy check. Among the herbicides, oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ were found effective and increased all these parameters to a greater extent.
6. The important growth analysis parameters *viz.*, leaf area, AGR, CGR, NAR, SLW, LAD and BMD were significantly higher in weed free treatment and these values were found to be the lowest in weedy check. Among the herbicides, oxadiazon @ 0.5 and 0.4 a.i. ha⁻¹ was very effective and increased all these growth parameters to a greater extent. However, the parameters *viz.*, RGR, LAR and SLA were found to be more in weedy check treatment as compared to other treatments.
7. The bulb yield was significantly higher in weed free treatment and decreased significantly due to weed competition. Among the herbicides, bulb yield was significantly higher with oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ followed by pendimethalin @ 1.0 kg a.i. ha⁻¹ and oxyfluorfen @ 0.15 kg a.i. ha⁻¹.
8. The weed index values were significantly higher in weedy check and among the herbicides, oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ recorded significantly lower values for weed index.
9. Among the biochemical parameters, the total chlorophyll content was significantly higher in weed free treatment and was found to be lowest with crop weed competition. The herbicide oxadiazon @ 0.5 and 0.4 kg

- a.i. ha^{-1} significantly increased the total chlorophyll content as compared to weedy check.
10. From the point of economics, the benefit cost ratio was highest with the application of oxadiazon @ $0.4 \text{ kg a.i. ha}^{-1}$ followed by oxadiazon @ $0.5 \text{ kg a.i. ha}^{-1}$ as compared to other herbicides.
 11. The application of oxadiazon @ $0.4 \text{ kg a.i. ha}^{-1}$ can be recommended for effective control of weeds in onion.

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VII. REFERENCES

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PHYSIOLOGICAL STUDIES ON WEED CONTROL EFFICIENCY IN ONION (*Allium cepa* L.)

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1999

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Major Advisor

ABSTRACT



A field experiment was conducted at Man Research Station, University of Agricultural Sciences, Dharwad during *kharif* 1999 to study the influence of herbicides and crop weed competition on weed control efficiency in onion (Cv.Nasik Red). The experiment consisted of five herbicides each at two concentrations and treatments with weed free and weedy check and was laid out in randomized block design with three replications.

Results revealed that the application of oxyfluorfen was phytotoxic while, oxadiazon @ 0.4 and 0.5 kg a.i. ha⁻¹ was not phytotoxic. The monocot, dicot and total number of weeds and total dry weight of weeds were found to be maximum in weedy check and the herbicide treatments oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ decreased these parameters. The weed control efficiency was maximum with oxadiazon @ 0.5 kg a.i. ha⁻¹.

The morpho-physiological trends *viz.*, leaf dry weight, bulb dry weight and total dry weight were lowest in weedy check and the application of oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ increased these parameters. The growth parameters *viz.*, leaf area, AGR, CGR, NAR, SLW, LAD and BMD were significantly lower in weedy check and application of oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ was very effective and increased these parameters.

The bulb yield decreased significantly due to weed competition and among the herbicides, bulb yield was significantly higher in oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ followed by pendimethalin @ 1.0 kg a.i. ha⁻¹ and these treatments recorded significantly lower values for weed index. The total chlorophyll content was significantly lower in weedy check and the application of oxadiazon @ 0.5 and 0.4 kg a.i. ha⁻¹ significantly increased chlorophyll content. The benefit cost ratio was highest with oxadiazon @ 0.4 kg a.i. ha⁻¹ followed by oxadiazon @ 0.5 kg a.i. ha⁻¹.