EFFECT OF POST-EMERGENCE HERBICIDES ON WEED CONTROL IN LAWN (*Cynodon dactylon* L.) SELECTION NO. 1

Thesis

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
in
HORTICULTURE (FLORICULTURE & LANDSCAPING)
(Minor Subject: Botany)

By

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CERTIFICATE I

This is to certify that the thesis entitled, "**Effect of post-emergence herbicides on weed control in lawn (C*ynodon dactylon* L.) Selection No. 1**" submitted for the degree of **M.Sc.**, in the subject of **Horticulture (Floriculture & Landscaping)** (Minor subject: **Botany**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Gurinder Singh (L-2019-H-395-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE II

This is to certify that the thesis report entitled, "**Effect of post-emergence herbicides on weed control in lawn (*Cynodon dactylon* L.) Selection No. 1**" submitted by **Mr. Gurinder Singh** (**L-2019-H-395-M**) to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **M.Sc.** in the subject of **Horticulture** (**Floriculture & Landscaping**) (Minor subject: **Botany**) has been approved by the Student's Advisory Committee along with the External Examiner after an oral examination on the same.

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ABSTRACT

The present study entitled "Effect of post-emergence herbicides on weed control in lawn (C*ynodon dactylon* L.) Selection No. 1" was conducted in established lawns at three different locations at Punjab Agricultural University, Ludhiana campus during both winter and summer season of year 2021. The experiment was laid out in randomized complete block design with 15 treatments replicated thrice. Fifteen treatments comprised isoproturon (0.937 kg ha^{-1}), mesosulfuron + iodosulfuron (0.014 kg ha^{-1}, clodinafop + metribuzin (0.216 kg ha^{-1}), 2,4-D amine (0.500 kg ha^{-1}), bispyribac sodium (0.025 kg ha^{-1}) metribuzin (0.120 kg ha^{-1}), metsulfuron (0.005 kg ha^{-1}), carfentrazone-ethyl (0.020 kg ha^{-1}), metsulfuron + carfentrazone-ethyl (0.025 kg ha^{-1}), metsulfuron-methyl + chlorimuron-ethyl (0.004 kg ha^{-1}), ethoxysulfurin (0.018 kg ha^{-1}), halosulfuron (0.050 kg ha^{-1}), atrazine (1.000 kg ha^{-1}) including two hand weedings (at 15 days interval) and un-weeded control. The results revealed that clodinafop + metribuzin (0.216 kg ha^{-1}) reduced the weed density and dry weight of *Digitaria sanguinalis* and *Dactyloctenium aegyptium*. Isoproturon (0.937 kg ha^{-1}) provided complete control of *Poa annua* whereas bispyribac sodium (0.025 kg ha^{-1}) was found effective against *Dicanthium annulatum* upto 60 days after spray (DAS). Weed density and dry weight of *Paspalum dilatatum* weed was markedly reduced by mesosulfuron + iodosulfuron (0.014 kg ha^{-1}). Metsulfuron + carfentrazone-ethyl (0.025 kg ha^{-1}) provided complete control of broadleaf weeds (*Gnaphalium purpureum*, *Oxalis corniculata*, *Veronica agrestis*, *Desmodium triflorum*, *Coronopus didymus*, *Erigeron canadensis*, *Stellaria media*, *Boerhavia diffusa* and *Alysicarpus vaginalis*) upto 60 DAS. Halosulfuron (0.050 kg ha^{-1}) effectively controlled *Cyperus rotundus* upto 45 DAS. Metsulfuron + carfentrazone-ethyl (0.025 kg ha^{-1}) (85.5%) recorded highest weed control efficiency (WCE) in winter season whereas clodinafop + metribuzin (0.216 kg ha^{-1}) (46.2 %) and bispyribac sodium (0.025 kg ha^{-1}) (43.5 %) recorded highest WCE in summer season. Sward height and dry weight of turfgrass was found negatively correlated with the weed density. Turfgrass phytotoxicity was observed in clodinafop + metribuzin (0.216 kg ha^{-1}) however, the grass recovered after 35 DAS in winter season, whereas in summer season, no phytotoxicity symptoms appeared. Turfgrass colour rating of eight was adjudged at all the locations during both the seasons.

Keywords: Turfgrass quality, *Cynodon dactylon* L., weed management, herbicides.

Signature of Major Advisor **Signature of the Student**

ਖੋਜ ਪ੍ਰਬੰਧ ਦਾ ਸਿਰਲੇਖ	:	ਘਾਹ (*Cynodon dactylon* L.) ਦੇ ਮੈਦਾਨ ਵਿੱਚ ਨਦੀਨਾਂ ਦੀ ਰੋਕਥਾਮ ਲਈ ਨਦੀਨ-ਨਾਸ਼ਕਾਂ ਦਾ ਪ੍ਰਭਾਵ
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ਸਾਰ-ਅੰਸ਼

ਵਰਤਮਾਨ ਅਧਿਐਨ ਦਾ ਸਿਰਲੇਖ ਹੈ “ਘਾਹ (*Cynodon dactylon* L.) ਦੇ ਮੈਦਾਨ ਵਿੱਚ ਨਦੀਨਾਂ ਦੀ ਰੋਕਥਾਮ ਲਈ ਨਦੀਨ ਨਾਸ਼ਕਾਂ ਦਾ ਪ੍ਰਭਾਵ” ਅਧੀਨ ਸਾਲ 2021 ਦੀਆਂ ਸਰਦੀਆਂ ਅਤੇ ਗਰਮੀਆਂ ਦੇ ਮੌਸਮ ਦੌਰਾਨ ਪੰਜਾਬ ਐਗਰੀਕਲਚਰਲ ਯੂਨੀਵਰਸਿਟੀ, ਲੁਧਿਆਣਾ ਵਿਖੇ ਤਿੰਨ ਵੱਖ-ਵੱਖ ਥਾਵਾਂ 'ਤੇ ਸਥਾਪਤ ਘਾਹ ਦੇ ਮੈਦਾਨ ਵਿੱਚ ਖੋਜ ਕੀਤੀ ਗਈ। ਤਜ਼ਰਬੇ ਨੂੰ ਬੇਤਰਤੀਬ ਸੰਪੂਰਨ ਬਲਾਕ ਡਿਜ਼ਾਈਨ ਵਿਚ 15 ਉਪਚਾਰਾਂ ਨਾਲ ਤਿੰਨ ਵਾਰ ਦੁਹਰਾਇਆ ਗਿਆ। ਨਤੀਜੇ ਦਰਸਾਂਉਂਦੇ ਹਨ ਕਿ ਕਲੋਡੀਨਾਫੋਪ + ਮੈਟਰੀਬੁਜ਼ਿਨ (0.216 ਕਿਲੋਗ੍ਰਾਮ ਪ੍ਰਤੀ ਹੈਕਟੇਅਰ) ਨੇ ਤੱਕੜੀ ਘਾਹ ਅਤੇ ਮਧਾਣਾ ਨਦੀਨ ਦੀ ਘਣਤਾ ਅਤੇ ਸੁੱਕੇ ਮਾਦੇ ਨੂੰ ਘਟਾ ਦਿੱਤਾ। ਇਹ ਵੀ ਦੇਖਣ ਵਿੱਚ ਆਇਆ ਕਿ ਆਈਸੋਪਰੋਟਿਊਰੋਨ (0.937 ਕਿੱਲੋ ਪ੍ਰਤੀ ਹੈਕ.) ਨੇ ਘੂਈਂ ਨਦੀਨ ਦੀ ਪੂਰੀ ਰੋਕਥਾਮ ਕੀਤੀ ਜਦੋਂ ਕਿ ਬਿਸਪਾਈਰੀਬੈਕ ਸੋਡੀਅਮ (0.025 ਕਿੱਲੋ ਪ੍ਰਤੀ ਹੈਕ.) ਦੇ ਛਿੜਕਾਅ ਤੋਂ ਭਲਵਾਨ ਘਾਹ ਤੇ 60 ਦਿਨਾਂ ਤੱਕ ਪੂਰੀ ਤਰ੍ਹਾਂ ਰੋਕਥਾਮ ਰਹੀ। ਮੇਸੋਸਲਫੂਰੋਨ + ਆਈਡੋਸਲਫੂਰੋਨ (0.014 ਕਿੱਲੋ ਪ੍ਰਤੀ ਹੈਕ.) ਦੇ ਛਿੜਕਾਅ ਨੇ ਨੜ੍ਹੀ ਘਾਹ ਦੀ ਘਣਤਾ ਅਤੇ ਸੁੱਕੇ ਮਾਦੇ ਉੱਪਰ ਅਸਰ ਪਾਇਆ। ਚੋੜੇ ਪੱਤੇ ਵਾਲੇ ਨਦੀਨ (ਗਨਾਫਾਲੀਅਮ, ਖੱਟੀ ਬੂਟੀ, ਵੇਰੋਨਿਕਾ, ਡੇਸਮੋਡੀਅਮ, ਜੰਗਲੀ ਹਾਲੋਂ, ਦਰਿਆਈ ਬੂਟੀ, ਸਟਲਾਰੀਆ, ਬਿਸਖਪੜਾ, ਅਲੀਸੀਕਾਰਪਸ) ਦੀ ਮੈਟਸਲਫੂਰੋਨ + ਕਾਰਫੈਨਟ੍ਰਾਜ਼ੋਨ-ਈਥਾਈਲ (0.025 ਕਿੱਲੋ ਪ੍ਰਤੀ ਹੈਕ.) ਨੇ ਸੰਪੂਰਨ ਰੋਕਥਾਮ ਪ੍ਰਦਾਨ ਕੀਤੀ। ਹੈਲੋਸਲਫੂਰੋਨ (0.050 ਕਿੱਲੋ ਪ੍ਰਤੀ ਹੈਕ.) ਨੇ ਮੋਥੇ ਨੂੰ 45 ਦਿਨਾਂ ਤੱਕ ਪ੍ਰਭਾਵਸ਼ਾਲੀ ਢੰਗ ਨਾਲ ਨਿਯੰਤਰਿਤ ਕੀਤਾ। ਮੈਟਸਲਫਰੋਨ + ਕਾਰਫੈਨਟ੍ਰਾਜ਼ੋਨ-ਈਥਾਈਲ (0.025 ਕਿੱਲੋ ਪ੍ਰਤੀ ਹੈਕ.) ਦੀ ਸਰਦੀਆਂ ਵਿੱਚ ਨਦੀਨਾਂ ਦੀ ਰੋਕਥਾਮ ਕਰਨ ਦੀ ਕੁਸ਼ਲਤਾ 85.5 ਪ੍ਰਤੀਸ਼ਤ ਆਂਕੀ ਗਈ, ਜਦ ਕਿ ਕਲੋਡੀਨਾਫਾਪ + ਮੈਟਰੀਬੁਜ਼ਿਨ (0.216 ਕਿੱਲੋ ਪ੍ਰਤੀ ਹੈਕ.) ਅਤੇ ਬਿਸਪਾਈਰੀਬਾਕ ਸੋਡੀਅਮ (0.025 ਕਿੱਲੋ ਪ੍ਰਤੀ ਹੈਕ.) ਦੀ ਗਰਮੀਆਂ ਦੇ ਮੌਸਮ ਵਿੱਚ ਕੁਸ਼ਲਤਾ ਸਭ ਤੋਂ ਵੱਧ (ਕ੍ਰਮਵਾਰ 46.2 % ਅਤੇ 43.5 %) ਰਿਕਾਰਡ ਕੀਤੀ ਗਈ। ਘਾਹ ਦੀ ਲੰਬਾਈ ਅਤੇ ਸੁੱਕਾ ਮਾਧਾ ਨਦੀਨਾਂ ਦੀ ਘਣਤਾ ਦਾ ਨਕਾਰਾਤਮਕ ਤੌਰ ਤੇ ਸਬੰਧ ਪਾਇਆ ਗਿਆ । ਕਲੋਡੀਨਾਫੋਪ + ਮੈਟ੍ਰੀਬੁਜ਼ਿਨ (0.216 ਕਿਲੋ ਪ੍ਰਤੀ ਹੈਕ.) ਦਾ ਘਾਹ ਤੇ ਜਹਰੀਲਾਪਨ ਦੇਖਿਆ ਗਿਆ ਜੋ ਕਿ ਸਰਦੀਆਂ ਦੇ ਮੌਸਮ ਵਿੱਚ 35 ਦਿਨਾਂ ਬਾਅਦ ਘਾਹ ਬਿਲਕੁੱਲ ਹਰਾ-ਭਰਾ ਅਤੇ ਨਿਰੋਆ ਹੋ ਗਿਆ ਸੀ। ਗਰਮੀਆਂ ਦੇ ਮੌਸਮ ਵਿਚ ਨਦੀਨ ਨਾਸ਼ਕਾਂ ਦੇ ਕੋਈ ਵੀ ਜਹਿਰੀਲੇਪਨ ਦੇ ਲੱਛਣ ਦਿਖਾਈ ਨਹੀਂ ਦਿੱਤੇ। ਦੋਵੇਂ ਮੌਸਮਾਂ ਦੌਰਾਨ ਘਾਹ ਰੇਟਿੰਗ ਸਕੇਲ ਤੇ ਅੱਠ ਨੰਬਰ ਆਂਕੀ ਗਈ।

ਮੱਖ ਸ਼ਬਦ: ਘਾਹ, ਨਦੀਨ ਰੋਕਥਾਮ, ਖੱਬਲ ਘਾਹ, ਘਾਹ ਦਾ ਮੈਦਾਨ, ਨਦੀਨ ਨਾਸ਼ਕ, ਨਦੀਨ ਪ੍ਰਬੰਧਨ

______________________ ______________________

ਪ੍ਰਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖ਼ਰ **ਵਿਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖ਼ਰ**

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CHAPTER - I

INTRODUCTION

A lawn is an indispensable feature of a landscape with a greater proportion of space relative to other garden features. The name 'Lawn' is derived from the Brittonic word 'Landa' (old French: Launde) means coarse grass and barren land. A lawn is the heart of any good garden and enhances the beauty of the landscape and is an essential and basic architectural feature for modern gardening. Lawns are generally maintained with a short height (not more than 5 cm) and trimmed alongside flower beds to demarcate the boundary as edging. (Siddappa *et al* 2016).

The lawns are common features of private gardens, public landscapes and parks for aesthetic pleasure, outdoor recreational uses and out-door sports viz; badminton, cricket, field hockey, golf, lawn bowling, lawn tennis, volleyball, etc. are performed in the lawns. Also, turf grasses give security and clean control along with a huge number of miles of express ways and a huge number of airport runways. Walking on the lawn enhances psychological wellness through a positive remedial effect which helps to cure sickness particularly by lessening the danger of coronary illness and diabetes. Turfgrass contributes to social harmony and improved productivity. In addition, turfs also provide better exercising opportunities for human well-being (Janakiram and Namita 2015).

Grasses are biologically predominant species that cover roughly 20 per cent of the world's surface. The grass family incorporates about 10,000 species ordered into 600 to 700 genera which extend from a little and finely finished vegetation developed stature of 2.5 cm to the huge bamboos which may reach a height of 30 m. The grasses have a place with class of monocots and family Poaceae. The monocots are blossoming plants that have one cotyledon in their seed and have parallel leaf venation with vascular bundles arrangement in the stem. Turfgrass industry in India has been estimated with a land cover of more than 30,000 acres, out of which around 4,500 acre is under lawn cultivation in diverse urban landscapes. Ganu Farm Group, is the leading turf supplier in India covering 300 acres under high quality turfgrass production. Apart from that good quality turf or sod is being produced in small farms and nurseries throughout India which caters our domestic needs of turf as well some suppliers are exporting it to Sri Lanka and Middle East countries on small scale.

A well maintained lush green carpet provides an opportunity for people to relax, engage in passive and active recreation apart from holding social gatherings (Ignatieva *et al* 2015). The lawns also add a feeling of happiness to the garden on warm summer days. Due to the huge extent of urbanization which has led to diminishing space, a lawn assumes massive consequence. A lawn bonds your house and landscape simultaneously and makes the house looks better. Vigorously growing and weed free lawn attract people to the site creating a positive impact on the property It helps to improve environmental quality. Grasses are also able to absorb other atmospheric pollutants, including ozone, sulfur dioxide, nitrogen dioxide, ammonia, carbon monoxide, volatile organic compounds and lead (Stier *et al* 2013) water infiltrates and passes through the grass, thatch and soil, it is filtered and cleansed by microorganisms that digest and degrade organic chemicals or pollutants (Beard and Green 1994). Turfgrasses can both conserve and improve soil by reducing sediment losses and adding organic matter to the soil. The extensive fibrous root system helps to knit the soil together that helps to reduce erosion. The structure and density of turf help to reduce noise and glare. Turf absorbs jarring noises considerably better than paved surfaces and also reduces the multidirectional light reflectance causing glare. Compared to an urban walk along a busy street, a nature walks through grasslands with scattered shrubs and oak trees lead to decreases in anxiety, rumination and negative emotions (Bratman *et al* 2015).

Turf is an ideal to absorb and assimilate bio-solids as a fertilizer and recycled water for irrigation. A well-maintained lawn checks soil erosion and mitigates the impact by intercepting the raindrops thereby minimizing water run-off and helps to increase the efficiency of water percolation which in turn maintains the soil moisture and aids in recharging the groundwater. Besides, a well-maintained dense patch of lawn works as an acoustic element by deflecting excessive sound of adjoining vehicular traffic which is a major nuisance in the urban areas. A lawn is also thought to be an effective bio-remediator of synthetic organic compounds which are often sprayed periodically for its maintenance. Lawns provide open space for recreational activities and relaxation as well as a mean to ameliorate heat and dust (Turgeon 1999). The turfgrass also regulates the temperature of the surroundings particularly during summer through evapotranspiration, thereby appreciably work as exterior air conditioners.

The magnitude of a lawn being the highest in proportion to its surrounding landscape features effectively absorbs dust and particulate matter from the atmosphere and helps in sequestering gases like carbon dioxide (CO_2), sulphur dioxide (SO_2) and other harmful gases, thus act as an effective buffer in urban areas. A lawn measuring 50′ × 50′ can produce enough oxygen required for a family of four (Beard 2016). In India, due importance is being given now to landscaping resulting in an increase in the area under the turf in both rural as well as urban areas. India needs in the turf industry, is contemporary research and trained manpower. The primary research may include, testing new varieties or products, breeding new varieties from native grasses, testing new maintenance procedures, improved cultural practices, weed control and other improvements and advanced research has no limitations as it can be carried out on different aspects of turfgrasses on global warming, carbon sequestration, Phyto-remediation, etc. 1m area of turf gives highest returns if compared with returns from fruits, vegetables, cereals and ornamentals from the same area. As the benefit cost ratio is very high, it needs to be taken up by the farmers provided the technical consultancy is present readily.

Bermuda grass (*Cynodon dactylon*, having chromosome number 2n=18), also called Doob grass, Bermuda grass, dubo, Dog's tooth grass, Bahama grass, Devil's grass, Couch grass and Scutch grass, originated in North and East Africa, Asia, Australia and Southern Europe (McCarty and Miller 2002). It is a major type of turf species for sports fields, yards, parks, fairways and general utility turfs. Bermuda grass is a warm-season perennial specie changed as tropical and sub-tropical environment. It grows best under extended conditions of high temperature, smooth winter and more precipitation. Although Bermuda grass seed has been accessible for a long time, its utilization in high-value turfs was increased in recent years because of the release of new cultivars with superior turfgrass quality similar to hybrid Bermuda grass. The advantage of seeded Bermuda grass is that it can be built up at a lower cost as compared with sodding or sprigging (Patton *et al* 2004). Bermuda grass has a fibrous root system which arises at the nodes with deep rhizomes. New leaves are produced from runners or stolons during the growing season. *Cynodon* spp. can be grown under irrigated as well as dry and semi-arid conditions (Holm *et al* 1977).

Bermuda grass (*Cynodon* spp.) is the most widely planted as turfgrass with several desirable traits including drought resistance, trespassing tolerance, disease resistance and relatively better recuperative potential (Zhang *et al* 2017). However, it has become a common observation of weed infestation in improved strain (Selection No.1) of Bermuda grass species. A weed is a plant that grows where it is not wanted, like a dandelion in a turf. Infestation of weeds in turfgrass not only compete for moisture, nutrients, sunlight and space but also invite insects and disease causing organisms to make their habitat besides rendering it useless for active or passive recreation (Busey 2003). It is pertinent to address this issue for maintaining a healthy, lush green and weed-free lawn. It has been observed that altering agronomic practices to reduce the competitiveness of one weed simply may cause other weed species to re-appear. Therefore, due to the omnipresent nature of the weeds, an integrated approach to weed control along with application of herbicides should be followed to curtail the spread of weeds and maintain the quality of turfgrass (Uddin *et al* 2012).

Periodic cultural practices such as timely mowing, need-based irrigation, balanced fertilization and manual weeding are done to maintain the vigour and quality of a lawn. It has been postulated that after mowing of a lawn, grass clippings so obtained should be left over for recycling of nutrients back to soil nutrient pool through mineralization and decomposition by soil microbes (Beard 2016). The nutrient content in grass clippings varies as Nitrogen (3-4 %), Phosphorus (0.5-1.0 %) and Potassium (1-2 %) and therefore, the recycling of grass clippings periodically during mowing reduce the need of fertilizers by as much as 25 per cent. Returning grass clippings through mulching is beneficial (Knot *et al* 2017); however, the accumulated thatch of cut grass will also reduce the efficacy of applied herbicide. Lawn grass can also be categorized depending upon its usage and season of plantation. There are assured lawn grasses that prefer a warm and humid temperature viz; *Paspulum notatum* (Bahia grass), *Cynodon dactylon* (Bermuda grass), *Eremochloa ophiuroides* (Centipede grass), *Axonopus affinis* (Carpet grass), *Buchloe dactyloides* (Buffalo grass), *Zovsia japonica* (Japanese lawn grass), *Zoysia tenuifolia* (Mascarene grass). The grasses used for the development of lawns which favour cool and dry weather are *Poa annua* (Annual bluegrass), *Lolium multiflorum* (Annual ryegrass), *Agrostis tenuis* (Bentgrass), *Festuca ovina* (Hard fescue), *Festuca arundianacea* (Tall fescue) etc. (Tiwari 2012).

A major confront with lawn management is the increased incursion by different weed species. The primary methods of weed management are physical or mechanical, chemical, biological and integrated. A mechanical method of weed control is good but has many disadvantages viz; high cost of weed removal, disrupts turf roots, exposes organic matter of soil to oxidation, suppression of turf growth due to trampling and not possible on large scale. Hand weeding must be recurring 2-3 times before the lawn has fully established (Siddappa *et al* 2015a). The conventional practice of hand weeding is regarded as the most preferred methods to rogue out the weeds but often becomes impractical in larger areas where manual weeding is not feasible due to cost of labour (Srinivasarao *et al* 2014).

Recent supervision of lawn weeds depends on the use of herbicides. This is due to a lack of valuable alternatives and a comparatively low tolerance for weeds in the lawn ecosystem (Doughlas *et al* 2005). After the establishment of the lawn, weeds are restricted by using herbicides as pre-emergence or post-emergence to control broadleaf and sedges. Pre-emergence herbicides are applied to the soil before the weed seeds germinate, most of these moved into the soil by rain or irrigation and will be taken up by the roots and shoots of the weeds. Soil residual activity depends upon the herbicidal group and rate of application. Post-emergence herbicides used in lawn grass for weed control either translocate or act as a contact herbicide. These herbicides translocate into the leaves and stem, move in the xylem and phloem and finally reach the target site where these interfere with plant processes, ultimately cause mortality of weeds.

Since then, a number of selective and broad-spectrum herbicides have been evolved and recommendations have been proposed to eradicate weeds from the wastelands, cereal and horticultural crops. Literature pertaining to weed management with an application of selective herbicides for checking the growth of grasses, broadleaf weeds and sedges in Bermuda grass *Cynodon dactylon* var. Selection No.1 is deficient.

Keeping the above points in view, the study entitled "Effect of post-emergence herbicides on weed control in lawn (*Cynodon dactylon* L.) Selection No. 1" was conducted with the following objective.

1. To study the effect of post-emergence herbicides spray on weed management in lawn.
2. To study the effect of post-emergence herbicides on turfgrass quality.

CHAPTER - II

REVIEW OF LITERATURE

Weed control is an essential practice to maintain the aesthetics of a lawn. Several weed management approaches have been purported by agronomists and weed specialists worldwide. An attempt has been made in this regard to collect, systematize and present the review of literature (year 1964 to 2021) on different aspects of weed management in lawn, that is presented in this chapter under the following sub-heads:

2.1: Bermuda grass: Habitat and characteristics

2.2: Turfgrass quality

2.3: Weed flora of Turfgrass

2.4: Mechanical and cultural control of weeds

2.5: Chemical control of weeds

 2.5.1: Applied as pre-emergence

 2.5.2: Applied as post-emergence

 2.5.3: Combination of chemicals

2.6: Herbicides induced turfgrass phytotoxicity

2.7: Economics of weed control

2.1: Bermuda grass: Habitat and characteristics

Bermuda grass, is primarily a warm season grass and is a native turfgrass species of Africa. There are nine species in the genus 'Cynodon', out of which *Cynodon dactylon* is most widely used as an amenity turfgrass species. This grass is known by other names such as couch grass, green couch and doub or doob grass (Taliaferro 1995) and has been popular due to its several desirable traits, the most important being its tolerance of low mowing height. Bermuda grass possesses an appreciable drought resistance, exhibit tolerance to repeated trespassing, low to moderate fertilization, appreciable disease resistance and also had a relatively good rejuvenating potential (Zhang *et al* 2017). The selections and strains of Bermuda grasses have been observed to establish rapidly as a turf and perpetuate itself vegetatively both through stolons (above ground stems) and rhizomes (below ground roots). The grass establishes well under open sunny situations either at residential lawns, athletic fields, golf courses, embankments or other amenity turf areas. With the evolution of new hybrid turfgrass cultivars, involving interspecific crosses of *Cynodon dactylon* and *Cynodon transvaalensis*, a superior and refined turfs have been evolved offering improved levels of quality, density and colour of the grass in addition to abiotic stress tolerances. Direct seeding of Bermuda grass makes it more popular and cost effective to cover extensive areas as compared with sodding or sprigging (Patton *et al* 2004). Being a warm season grass, it tends to lose its chlorophyll and turns brownish-yellowish under cooler soil temperatures (Below 10^{o} C). However, the grass regains its colour with the rise in soil temperature (15-20^{o} C) during early spring and summer season. The bermuda grass grow profusely at a temperature range of 15-20^{o} C and continue to grow actively round the year, except during period of cool temperatures.

2.2: Turfgrass quality

The colour of the turf is a qualitative attribute which can be observed and classified visually. The scores (1-9) viz; 1 – yellow green, 2 – olive green, 3 – light green, 4 – grey green, 5 – luscious green, 6 – green, 7 – grassy green, 8 – dirty green, 9 – emerald is used to distinguish between green colour according to Royal Horticultural Society Colour Chart (RHSCC, Edition V) (Voss, 2002).

Cedergreen (2008) investigates the growth response and biomass allocation pattern of barley exposed to 10–15 doses of eight different herbicides. The results show that glyphosate, together with the sulfonylurea and metsulfuron-methyl can induce a real stimulation in biomass growth of approximately 25 per cent when applied at doses corresponding to 5-10% field rate. The other six herbicides tested did not induce consistent hormesis.

Patton *et al* (2010) characterized zoysia grass cultivars based on colour density, turf quality, thatch accumulation and disease incidence subjected to mowing and N fertilization treatments (urea, ammonium nitrate and calcium nitrate) were applied as 0.9 kg and 1.8 kg N per 1000 square feet per year with each source and their interactions. In addition, the mandate of the experiment was to establish appropriate mowing height and nutrition recommendations for each zoysia cultivars. The results indicated that turf quality was the highest for 'Meyer' and 'Cavalier'. Turf quality was adjudged the highest in the spring season and it was also observed that the N source did not affect turf quality.

Cutulle *et al* (2014) conducted a field trial to evaluate the effect of fertility programs and mowing height on disease severity and encroachment of bermuda grass. The findings revealed that mowing the bermuda grass at 10 cm height from ground level resulted in relatively less encroachment compared to the mowing height at 6 cm however, it was observed that increasing the N fertilization level 49 to 171 and 220 kg N ha^{-1} resulted in more encroachment of Bermuda grass at 6 cm height. Turfgrass cover was found denser in plots where the mowing height was kept 10 cm.

Wadekar *et al* (2018) conducted a morphological evaluation of nine turfgrasses. Korean grass (*Zoysia japonica*), American Blue grass (*Poa pratensis*) exhibited green colour. All turf grasses exhibited fine leaf texture except Weeping love grass (*Eragrostis curvula*) which had a medium coarse texture. Argentine grass (*Paspalum notatum*), St. Augustine grass (*Stenotaphrum secundatum*) and Phosphelone grass exhibited a coarse texture. The highest ground cover (100%) was observed in American blue grass (*Poa pratensis*) and Bermuda grass (*Cynodon dactylon*) at 60 DAT. The maximum chlorophyll content (69.59 mg/100g) was recorded by Bermuda grass (*Cynodon dactylon*) and maximum shoot length was recorded in

Phosphelone grass (80.82 cm) and Argentine grass (*Paspalum notatum*) 6.95 mm. The maximum leaf length range between (45.07-50.43 cm) recorded in Weeping love grass (*Eragrostis curvula*) and showed maximum root length (21.74 cm) which was found significantly superior compared to rest of the turfgrasses.

2.3: Weed flora of Turfgrass

It is essential to identify the weeds in a lawn and know their growth habit, period of emergence, response to mowing and persistence to herbicide sprays that would help to under an appropriate decision to check their growth. Emergence of weed flora in different turfgrasses varies under different climatic conditions viz: winter, spring, summer, hot and rainy weather etc. In general, the turfgrass weeds are classified broadly in to monocotyledonous (monocots) and dicotyledonous (dicots) plants. Morphologically, monocots can be distinguished with the presence of one seed-cotyledons during seed germination; and dicots possess two seed cotyledons during seedling emergence. The sic commonly occurring weed types found in turf grasses are grasses, broadleaf, spiderworts, rushes, lilies and sedges.

Among the broadleaf weeds, *Euphorbia hirta*, *Euphorbia microphylla*, *Launaeaa splenifolia*, *Conyza stricta* and *Indigofera glandulosus* were the dominant species during rainy season, whereas *Medicago denticulata*, *Melilotus alba*, *Trigonella polycerata*, *Polycarpaea corymbosa* and *Euphorbia microphylla* were major broadleaf weeds in lawn Bhat (1975).

Bhowmick *et al* (2005) reported the results that major weed flora in wasteland of rice research station, Chinsurah, West Bengal constituted *Cynodon dactylon, Eleusine indica, lmperata cylindrica, Cyperus rotundus, Blalnvillea latifolia, Heliotropium indicum and Parthenium hysterophorus*.

Wiecko (2006) observed that *Cyperus rotundus* was the most troublesome weed among sedges in tropical turfgrasses whereas, Kamal *et al* (2009) observed several weed flora in the experimental plots viz. *Panicum repens*, *Digitari amarginata among* (grasses), *Ageratum conyzoides, Alternanthera sessilis, Borreria articularis, Bidens pilosa, Cinebra didyma, Cyanotis* spp., *Desmodium triflorum, Emilia sanchifolia, Euphorbia hirta, Mimosa pudica, Parthenium hysterophorus, Oxalis latifolia, Phyllanthus niruri, Sida acuta, Chromalaena odorata and Tridax procumbens* among broadleaf weeds. The study further classified a total of 79 different weed species belonging to 16 families (30 grass weeds, 17 sedges and 32 broadleaf weeds) in turfgrass.

Asiedu *et al* (2012) conducted an experiment at central region of Ghana on turfgrasses maintained in 5m × 1.5m plots to determine the predominance of weed species. The observations revealed that *Boerhavia diffusa* and *Cyperus rotundus* were the predominant weed species. *Chrysopogon aciculatus* (Love grass) plots were heavily enchroached by weeds as compared to *Zoysia japonica* (Carpet grass) and *Stenotaphrum secundatum* (St. Augustine's grass) turfgrass species.

Common weeds observed in lawn were purple nutsedge (*Cyperus rotundus*), Clover (*Alysicarpus vaginalis*), Bari dodhak (*Euphorbia hirta*), Milkweed (*Sonchus arvensis*), Chhoti-dhodhak (*Euphorbia microphylla*), Roadsided itsit (*Boerhavia diffusa*), Horse purslane (*Trianthema portulacastrum*), Tin-patia (*Desmodium trifolium*), Khattibooti (*Oxalis corniculata*), Sandbur (*Cenchrus biflorus*), Love grass (*Eragrostis pilosa*), Takrighas (*Digitaria sanguinalis*), Maina (*Medicago denticulata*), Maini (*Trigonella polycerata*), Madhana (*Dactyloctenium aegyptium*), Congress grass (*Parthenium hysterophorus*), Salari (*Gompherena celosiodes*), Jangligobhi (*Launaea nudicalis*) and Baru (*Sorghum halepense*) as reported by Singh and Singh 2014 in their exhaustive study undertaken under subtropical climate of Punjab climate.

LeStrange and Reynolds (2016) characterized weed diversity in lawn as grass, broadleaf and sedges. The Bluegrass (*Poa annua*), Crabgrass (*Digitaria sanguinalis*), Goosegrass (*Eleusine indica*) and Dallis grass (*Paspalum dilatatum*) were classified as grassy weeds. Weeds such as Black medic (*Medicago lupulina*), California burclover (*Medicago polymorpha*), Common knotweed (*Polygonum aviculare*), Spurges (*Euphorbia* spp.), White clover (*Trifolium repens*), Dandelion (*Taraxacum officinale*), English daisy (*Bellis perennis*) and Buckhorn (*Plantago Coronopus*) were categorized under broadleaf weeds; and among sedges were Green kyllinga (*Kyllinga brevifolia*) and Nutsedge (*Cyperus rotundus*).

Singh (2018) conducted an experiment at Punjab Agricultural University, Ludhiana for weed control in lawn and observed that major weed species among broadleaf weeds were *Anagalis arvensis*, *Coronopus didymus*, *Convolvulus arvensis, Malva parviflora, Medicago denticulata, Euphorbia microphylla, Melilotus indica, Rumex dentatus, Amaranthus viridis, Chenopodium album*, *Gomphrena celosioides*, *Phyllanthus niruri*, *Celosia argentea, Parthenium hysterophorus, Ageratum conyzoides, Bidens pilosa, Alternanthera philoxeroides* and *Euphorbia hirta.* Weeds such as *Oxalis martiana* and *Cyperus rotundus* were categorized as sedges.

2.4: Mechanical and cultural control of weeds

Couillard and Wiecko (1998) reported that irrigating salt tolerant turfgrasses with ocean water was an effective alternative to chemical herbicides to control weeds.

Hatcher and Melander (2003) revealed that mowing a turfgrass at lower height (<3cm) potentially cause stress for broadleaf weeds during summer. It was also observed that mowing turfgrass at higher height (> 3 cm) resulted in higher humidity levels due to condensation of the dew droplets close to the soil surface. Increased humidity during early morning hours resulted in congenial environmental conditions for the pathogens to multiply and spread fungal diseases, that eventually harm the aesthetic quality of turfgrass.

Busey (2003) extensively reviewed the package of practices for Integrated Weed Management (IWM) involving timely mowing, adequate fertilization, need-based irrigation and a selection of suitable variety of turfgrass to suppress the weed populations. Contrary to the studies of Hatcher and Melander (2003), it was observed that turfgrasses mowed at taller height (4 to 8 cm) significantly reduced the populations of crab grasses (*Digitaria* spp.) in Kentucky bluegrass (*Poa pratensis* L.) and fescues (*Festuca* spp.). It was also observed that a higher rate of N fertilization (100–300 kg N ha^{-1}) was effective to maintain the growth and density of cool season turfgrasses besides suppressing the populations of crab grasses, dandelion (*Taraxacum officinale*) and other broadleaf weeds. However, the population density of annual bluegrass (*Poa annua* L.) was found higher at increased doses of N fertilization. The study undertaken (Busey 2003) was in conformity with the findings of Dunn *et al* (1981) who also reported that increased N levels, effectively checked the weed density of crabgrass and broadleaf weeds in cool-season turfgrasses.

Renner (2009) reported that non-manured plots yielded significantly lower weed populations (0.047 kg m^{-2}) as compared with plots that were supplemented with composted manure (0.07 kg m^{-2}). Analysis of the composted cow manure revealed that livestock fed with weed infested forage usually resulted in fecal matter rich in weed seeds, that retain their vitality as well as germination even after composting, which resulted in increased weed infestation after the compost is incorporated into soil.

Uddin *et al* (2012) revealed that mowing height was the key cultural factor to suppress the weed population. A lower mowing height has been associated with greater weed infestation in the turfgrass. Split application of N fertilizer at intervals throughout the growing period was recommended for warm season turfgrasses. However, it was observed that the application of N fertilizer during dormant periods might encourage weed growth. Hand pulling the weeds with intact roots and hoeing done at at optimum soil moisture, effectively controlled the emerging annual and biennial weed seedlings in lawn.

Uddin *et al* (2012) proposed that irrigating salt tolerant turfgrass species such as *Cynodon dactylon, Paspalaum vaginatum, Stenotaphrum secundatum* and *Zoysia japonica* with saltwater was found effective to control grasses, broadleaf and sedge weeds.

Li *et al* (2021) reported that mowing can be an effective method to reduce yellow nutsedge growth. Mowing at 7.6 cm weekly reduced yellow nutsedge rhizome dry mass by 55% and number of new tubers formed by 63% in the greenhouse study. Physical removal of yellow nutsedge plants such as hand-pulling can be an effective method to manage yellow nutsedge and is most effective at the three- to five-leaf stage.

2.5.2: Chemical control of weeds.

2.5.2.1: Applied as pre-emergence

Bingham (1974) revealed that pre-emergence herbicides such as bensulide, dithiopyr, benefit, oryzalin, pendimethalin, prodiamine, trifluralin were effective in control of broad spectrum of weeds on well-established turfgrass.

Dernoeden *et al* (1984) reported that benefin sprayed at 3.4 kg and oxadiazon sprayed at 4.5 kg ha^{-1} proved to effectively control (90-95%) goose grass (*Eleusine indica*) control in turfgrass. Pendimethalin applied at 4.5 kg ha^{-1} also provided effective results on *Eleusine indica*.

McAfee and Baumann (2007) confirmed that pre-emergence herbicides comprising atrazine, benefin, oryzalin and pendimethalin were effective to check annual grassy weeds whereas isoxaben and ethofumesate were found effective to control annual broadleaf weeds. Herbicide metolachlor was found to check the growth of sedges.

Sharma (2008) reported that nitrofen (2-5 kg ha^{-1}) sprayed as pre-emergence herbicide on turfgrass proved effective for the control of broad spectrum of weeds.

Kaapro and Hall (2011) reported that indaziflam herbicide was found effective for control of weeds in turfgrasses. The herbicide inhibited cellulose biosynthesis in weeds. It was also observed that turfgrass species exhibit tolerance to the applications of indaziflam applied at lower doses (0.050 kg and 0.150g ha^{-1}). Brosnan *et al* (2011) observed that weed density of smooth crabgrass (*Digitaria* spp.) varied with the herbicide application. Indaziflam sprayed at differential doses (0.035 kg ha^{-1}, 0.052 kg ha^{-1} and 0.070 kg ha^{-1}) at different seasons effectively controlled growth and development of smooth crabgrass.

Derr (2012) evaluated sulphonylurea herbicides for pre-emergence control of annual and perennial weeds in cool-season turfgrass species. The findings confirmed that sulfonylurea herbicides had a limited efficacy for broadleaf weed species and therefore was found ineffective in checking the weed growth.

LeStrange and Reynolds (2016) reported that pre-emergence herbicides viz; benefin+oryzalin, bensulide, oryzalin, prodiamine, pendimethalin and siduron were found effective to control grassy weeds whereas isoxaben checked the proliferation of broadleaf weeds, whereas herbicide metolachlor and mesotrione was found effective to suppress the growth of sedges.

Borah *et al* (2019) conducted an experiment to study the weed management practices in a doob grass (*Cynodon dactylon*) planted as an amenity lawn. The observations reported that pre-emergence application of pendimethalin (1kg ha^{-1}) followed by one hand weeding given after 45, 60 and 75 days after planting recorded the lowest weed density and weed dry weight, that was found non-competitive with the establishment of lawn.

Richard *et al* (2020) evaluated the effects of pre-emergence herbicides on establishment of golf course rough turfgrass on newly seeded 1:1 mixture of Little blue stem (*Schizachyrium scoparium*) and Sideoats grama (*Bouteloua curtipendula*). Herbicides applied immediately after drill seeding included atrazine, dimethenamid-P, dithiopyr, imazapic, indaziflam, isoxaben, Smetolachlor, oxadiazon, pendimethalin, prodiamine, and simazine. The plant density and biomass of smooth crabgrass [*Digitaria ischaemum*], were evaluated during two subsequent years (2017 and 2018). The herbicides Imazapic, Dimethenamid, Oxadiazon, and Metolachlor controlled more than 90% of crabgrass. In 2017, little bluestem plants resurged with 2-13 times the density that was assessed 4 months after imazapic herbicidal treatment.

2.5.2.2: Applied as post-emergence

Couch *et al* (1964) found that herbicide 2,4-D (1.79 kg ha^{-1}) and fenoxaprop at 0.447 kg ha^{-1} applied as post-emergence sprays (1.79 kg ha^{-1} and 0.447 kg ha^{-1} respectively) was able to suppress *Hypochaeris radicata*, *Oxalis stricta* and *Lespedeza stricta* weed growth in the established turf of bermuda grass.

Hollifield and Frans (1964) concluded the findings of an experiment that paraquat (0.271 kg ha^{-1}) suppressed growth and development of both annual weeds and grasses. However, paraquat sprayed at higher dose (0.543 kg and 1.08 kg ha^{-1}) was effective in controlling perennial broadleaf weeds without any visual phytotoxic injury to the bermuda grass (*Cynodon dactylon*) established turf.

Horn (1967) reported that out of the 37 herbicidal treatments assessed for the control of spurge (*Euphorbia maculata* and *Euphorbia* spp.) in a turf, only atrazine applied at 1.11 kg $ha^{-1}$was found effective in checking weed growth as compared with other herbicides.

Bhat (1975) reported that 2-3 applications of 2,4-D ester applied at 1.0 kg ha^{-1} and three applications of 2,4-D sodium salt applied at 1.5 kg ha^{-1} repeated at three weeks interval gave 100 percent control of weeds; whereas two applications of 2,4-D sodium salt and 2,4-D amine at 1.5 kg ha^{-1} repeated after 3-week intervals gave 91.09 and 94.8 percent control of weeds respectively.

Bingham (1985) concluded that herbicidal formulation of arsenicals with metribuzin applied at 0.28 to 0.56 kg ha^{-1}provides significant control of goosegrass, however, when this formulation was used alone, resulted in marginal tolerance to Bermuda grass. The herbicidal formulation was found to be used safely on well-established Bermuda grass maintained at mowing heights greater than 0.5 inch.

Bhowmik (1986) observed that fenoxaprop effectively controlled the growth of tillered crabgrass when herbicide is sprayed under adequate soil moisture.

Coats (1986) observed that asulam herbicide provides effective control of some annual grassy weeds without serious damage to St. Augustine grass provided the spray is done during period of actively growing turf and at average temperatures of 29.4˚C. However, it was observed that repeated applications at fortnightly intervals may be required for control of older weeds, with some visual damage to St. Augustine grass. Yellow nutsedge and annual sedges can be controlled effectively by spraying bentazon with minimal turf damage. Ashburn (1988) reported that post-emergence grass weeds were control by herbicidal formulations of organic arsenicals in cool-season turfgrasses.

Neal (1990) conducted a trial to find an alternative for non-phenoxy herbicides with 2,4-D for the management of broadleaf, dandelion and white clover in cool-season lawn grass.

The growth of broadleaf weeds was found suppressed by spraying of 2, 4-D (at the rate 0.84 kg ha^{-1}) herbicide. The spread of Dandelion (*Taraxacum* spp.) was checked by spray of 2,4-D (at the rate 0.84 kg ha^{-1})

McCarty *et al* (1991) reported that herbicide diclofop-methyl individually and formulation of organic arsenicals and metribuzin were effective to check the growth of goosegrass. Herbicide efficacy improved when turfgrass was maintained at lower mowing heights. Sharma and Sharma (1997) reported that all broadleaf weeds particularly *Veronica persica* can effectively be controlled by application of metsulfuron methyl applied at the rate of 0.004 kg ha^{-1}.

Ameena and George (2004) revealed that both the herbicidal treatments viz; Glyphosate (2.0 kg ha^{-1}) and 2,4-D Sodium salt (1.5 kg ha^{-1}) suppressed the growth of *Cyperus rotundus* and non-resurgence of this weed was observed up to six weeks after spraying. The tuber dry weights showed drastic reduction following herbicide application and glyphosate sprayed at 2.0 kg ha^{-1} recorded the least tuber dry weight values.

McAfee and Baumann (2007) reported that post-emergence herbicides viz; atrazine, carfentrazone, chlorsulfuron, 2,4-D and metsulfuron-methyl were used to control broadleaf weeds. Diquat, fenoxaprop and metribuzin were effectively controlled grassy weeds. Halosulfuron, imazaquin and sulfosulfuron were found effective to control the purple nutsedge weed.

McCarty *et al* (2008) reported that purple nutsedge (*Cyperus rotundus*) population density significantly got reduced with the spray of herbicides namely halosulfuron methyl and imazaquin to control purple nutsedge, with appreciable efficacy reported in former herbicidal treatment. Sharma (2008) reported that nitrofen sprayed at the rate of 2-5 kg ha^{-1} as post-emergence application in lawns proved effective for the control of wide spectrum of weeds.

McCurdy *et al* (2009) compared the effects of foliar, soil and soil + foliar applied mesotrione herbicide applied at 0.14 and 0.28 kg ha^{-1} on yellow nutsedge and large crabgrass. The population of yellow nutsedge and large crabgrass was checked by soil application of herbicide. In addition, mesotrione applied at 0.28 kg ha^{-1} gave effective control of both yellow nutsedge and large crabgrass more. Soil + foliar applied mesotrione at 0.28 kg ha^{-1} significantly controlled the large crabgrass population 28 days after treatment. Results indicate that root absorption of mesotrione from soil is more beneficial for the effective control of both yellow nutsedge and large crabgrass.

Yelverton and Gannon (2011) evaluated the effectiveness of sulfentrazone, sulfosulfuron and trifloxysulfuron as post-emergence for the control of purple Nutsedge and False-green kyllinga. Both sulfosulfuron and trifloxysulfuron provided more than 60 per cent control of purple nutsedge while sulfentrazone was found less effective (less than 30 per cent) for weed mortality. Admixtures of sulfosulfuron and trifloxysulfuron provided excellent (more than 85%) control of false-green kyllinga while sulfentrazone application alone provided less than 60 per cent control. The observations concluded that sulfosulfuron or trifloxysulfuron sprayed as post-emergence herbicidal sprays was effective in controlling perennial sedges in warm-season turfgrasses.

Derr (2012) evaluated sulphonylurea herbicides for post-emergence control of annual and perennial weeds in cool-season turfgrass species. It was observed that sulfonylurea herbicides had a limited coverage of broadleaf weed species and therefore was found ineffective in checking the weed growth in cool-season turfgrass species.

Mark and James (2013) reported that nicosulfuron and metsulfuron when applied sequentially at the rate of 0.039 kg ha^{-1} and 0.010 kg ha^{-1}, respectively controlled the sandbur (*Cenchrus* spp.) with 94 per cent reduction in population; whereas nicosulfuron applied at 0.059 kg ha^{-1} followed by second application at the rate of 0.013 kg ha^{-1} effectively, controlled the population of Johnsongrass, reporting nearly 88% reduction in population.

McCurdy *et al* (2013) conducted experiments to verify the tolerances amongst clover species of broadleaf herbicides. It was observed that only clover species exhibited variable reductions in height with the applications of imazaquin. It was purported that the differential clover response to herbicide treatment should be an important consideration when managing mixed grass–clover swards and should be taken into consideration for future research. Further, an array of herbicides (comprising atrazine, dicamba, clopyralid, 2,4-D, triclopyr, metsulfuron, and trifloxysulfuron) were identified that effectively controlled population density of clover species.

Hoseini-shoar and Armin (2015) studied that iodosulfuron+mesosulfuron had an undesirable phytotoxic effect on turf and the single spray was found ineffective to control the diverse weed flora. However, the single application of sulfosulfuron applied at 0.030 kg ha^{-1} was found to be effective in controlling weeds.

McCurdy *et al* (2015) evaluated the response of common lespedeza (*Lespedeza striata*) and centipede grass *(Eremochloa ophiuroides)* turf injury to broadleaf herbicides and commercial formulation herbicide mixtures sprayed during peak summer conditions. Fluroxypyr (sprayed at 0.47 kg ha^{-1}) alone and Escalade 2 (pre-packaged tank-mixture of 2,4-D, Fluroxypyr and Dicambaat) sprayed at 1.67 kg ha^{-1} effectively controlled common lespedeza without any turfgrass injury.

Siddappa *et al* (2015a) reported that application of herbicides 2,4-D Dimethyl amine (applied at 2.9 kg ha^{-1}), 2,4-D Sodium salt (1.6 kg ha^{-1}), 2,4-D dimethyl amine (2.18 kg ha^{-}1) and 2,4-D sodium salt (0.8 kg ha^{-1}), reported a weed control efficiency of 92.6, 91.9, 87.7 and 87.4 per cent, respectively after 60 days of application, which was found more effective (62.8%) than hand weeding done at 20 days interval. The findings suggested that 2,4-D sodium salt (0.8

kg ha^{-1}) and 2,4-D dimethyl amine (2.9 kg ha^{-1}) can be effectively used for the management of sedge and broadleaf weeds in lawn.

Danilo *et al* (2016) evaluated the selectivity of five herbicides over four grass species namely *Paspalum notatum*, *Cynodon dactylon*, *Zoysia japonica* and *Zoysia tenuifolia* for control of *Cyperus rotundus*. The findings revealed that Halosulfuron and 2,4-D herbicides were found selective to all of the grass species and checked the growth of weed species. The herbicide triclopyr was observed to be selective to *P. notatum*, *Z. japonica* and *Z. tenuifolia* and therefore it could be used to control the infestation of *C. rotundus* and *U. decumbens* in the above turfgrasses.

LeStrange and Reynolds (2016) reported that post-emergence herbicides viz; Fenoxaprop, Fluazifop, Sulfosulfuron were effective to control grassy weeds whereas Triclopyr and mixture of Triclopyr with MCPA and Dicamba effectively controlled broadleaf weeds. The herbicides Halosulfuron and Penoxsulam checked the growth of sedges.

Desai *et al* (2017) evaluated that Halosulfuron-methyl (75% WG) sprayed at 0.122 kg ha^{-1} was found effective to check the growth of sedge weeds while, the lowest ranking was recorded in glyphosate (41% SL) applied as foliar spray at the rate of 5.5l kg ha^{-1}. On the basis of visual phytotoxicity symptoms halosulfuron-methyl (75% WG) applied at the rate of 0.122 kg ha^{-1} had not shown any turfgrass phytotoxicity.

Singh (2018) revealed that the density of broadleaf weeds decreased to a greater extent in 2, 4-D amine applied at 580 g ha^{-1}. Halosulfuron sprayed at 0.067 kg ha^{-1} decreased the weed density of sedge drastically as compared to other herbicides. The weed control efficiency was the highest in hand weeding done at every 15 days interval. Among the herbicidal treatments, 2, 4-D amine applied at 580 g ha^{-1} recorded higher weed control efficiency and lower dry matter of broadleaf weeds. Halosulfuron sprayed at 0.067 kg ha^{-1} recorded the highest weed control efficiency (100 %) and recorded the lowest dry matter (0.71 g m^{-2}) of sedges.

Boeri *et al* (2021) conducted an experiment on nine genotypes of *Paspalum notatum* turf. Plants were grown under greenhouse conditions and 12 herbicides were applied at 1× and 2× labeled rates. Bentazon, bromoxynil, carfentrazone + 2,4-D + MCPP + dicamba and Carfentrazone were classified as safe. Fluroxypyr, halosulfuron and triclopyr + clopyralid reduced growth >50% when applied at twice the label rate.

2.5.2.3: Combination of chemicals

Hollifield and Frans (1964) showed that 2,4-D +Fenoxaprop sprayed at the rate of 0.940 kg ha^{-1} in dormant turf of bermuda grass (*Cynodon dactylon*) turf effectively checked emergence of broadleaf weeds without causing any phytotoxic injury to the turfgrass. Duich *et al* (1966) reported that herbicide mixture formulation comprising 2,4-D + Dicamba + Mecopropat applied at 0.261 kg ha^{-1} was found 100 per cent effective in controlling the growth of white clover and dandelion (*Taraxacum* spp.) in turfgrass.

Mathukima *et al* (2018) reported the maximum purple nutsedge weed control (92.20%) was reported 30 days after spraying mixture of glyphosate (1.23 kg ha^{-1}) + halosulfuron-methyl (0.080 kg ha^{-1}). The weed recorded lowest re-sprouting (5.76%) recorded 60 days after spraying.

2.6: Herbicides induced turfgrass phytotoxicity

Turf injury ratings were recorded weekly using a scale of 1 to 9, where 9 was attributed as no injury and 1 as completely necrotic turf. A rating below 6.5 indicated unacceptable turf injury, whereas a rating below 3.0 would indicate severe injury (Meyer and Branham 2006).

Michael *et al* (2011) reported that synthetic auxin herbicides were effective in control of broadleaf weeds without any adverse effect in several turfgrass species. However, herbicides such as Triclopyr and Aminocyclopyrachlor (AMCP) were known to injure warm season turfgrass species. The result of experiment indicated that relative to the labeled rates, of Triclopyr (0.56 to 1.12 kg ha^{-1}) and AMCP (0.053 kg ha^{-1}), Zoysia grass was the only turfgrass that exhibited symptoms of lack in vigor characterized by a reduction in turfgrass quality and green cover.

Boeri *et al* (2021) conducted an experiment on nine genotypes of *Paspalum notatum* turf. Plants were grown under greenhouse conditions and 12 herbicides were applied at 1× and 2× labeled rates. Fenoxaprop, sulfentrazone þ imazethapyr, and thiencarbazone þ iodosulfuron þ dicamba reduced growth and caused turfgrass injury above an acceptable threshold (≥20%). In general, the Argentine mutants showed greater herbicide injury compared to the Wilmington mutants. However, metsulfuron exceeded the acceptable injury threshold and stopped growth in all the genotypes, Argentine and genotype WT6 were the least injured by this herbicide. The experimental genotype WT6 consistently showed the greatest herbicide tolerance. Except for one genotype (WT4), the experimental genotypes responded similarly or better than Argentine to the tested herbicides, except for metsulfuron.

2.7: Economics of weed control

The highest cost incurred for management sedge and broad leaf weeds in lawn with *Cynodon dactylon* by hand weeding was Rs.26820/ha. Among herbicide treatments, carfentrozone ethyl 40 DF at (0.5 kg/ha) was Rs.5650/ha whereas lowest cost incurred for weed management in lawn 2, 4-D sodium salt 80 WP at (1.0 kg/ha) was Rs.894/ha followed by 2, 4-D sodium salt 80 WP at (1.5 kg/ha) was Rs.1041/ha. (Siddappa, 2015b)

Singh (2018) reported a saving of Rs.16755 ha^{-1} with the use of 2,4-D amine applied at 580 g ha^{1} which was significantly better than all other herbicidal treatment for the control of broadleaf weeds as compared with hand weeding treatment. Whereas, Halosulfuron applied at 67.5 g ha^{-1} recorded a saving of Rs.12605 ha^{-1} in weeding cost over hand weeding which was significantly better than other herbicidal treatments for control of sedges.

CHAPTER - III

MATERIALS AND METHODS

The materials and methods adopted in the study entitled, "Effect of post-emergence herbicides on weed control in lawn (C*ynodon dactylon* L.) Selection No.1" is presented in this chapter.

3.1: Location and agro-meteorological conditions

The study was conducted at Ludhiana, situated in trans-gangetic agro-climatic zone, representing the Indo-Gangetic Alluvial plain at 30° 56' N latitude, 75° 52' E longitude and at an altitude of 247 m above mean sea level. Ludhiana is characterized by sub-tropical semi-arid type of climate with hot summers and very cold winters. The mean maximum and minimum temperature show considerable fluctuation during summer and winter. The maximum temperature above 45^{o} C is common during summer and during winters the temperature falls below 4^{o} C occasionally. Frequent frosty spells are experienced during winters, especially in December and January. The total rainfall of 422.7 mm was recorded during the study period.

The meteorological data of air temperature, relative humidity and rainfall at Meteorological Observatory of Punjab Agricultural University, Ludhiana during experimental period from February 26th (week 9) to 30th April (week 18) has been presented in Fig. 1. The average minimum weekly temperature ranged between 11.9° to 21.4°C, average maximum weekly temperature ranged between 27.9° to 39°C with total rainfall 19.3 mm, while relative humidity ranged between 30.2 to 68.4 per cent during week 9 - 18. The average minimum weekly temperature ranged between 24.7° to 28.1°C and average maximum weekly temperature ranged between 29.8° to 35.3°C. The total rainfall of 403.4 mm was recorded with relative humidity ranging between 65.8 to 82.7 per cent during 30th July (week 31) to 24th September (week 39).

3.2: Physico-chemical characteristics of soil

A composite sample of soil was taken for physical and chemical analysis to determine the fertility status. The soil sample was air dried, ground and sieved through 2 mm sieve then subjected to analysis for physico-chemical properties (Table 3.1). The soil texture of the experimental sites selected during both the season was sandy loam, normal in soil reaction (pH ranging 8.0 to 8.3) with electrical conductivity (0.11 to 0.23 m mhos cm^{-1}). The organic carbon of the soil samples from different locations ranged 0.21 to 0.39 per cent. The available phosphorus ranged between 9.50 - 16.25 kg ha^{-1} whereas available potash ranged 155.00 - 337.50 kg ha^{-1} in soil samples representing different locations of the experimental site.

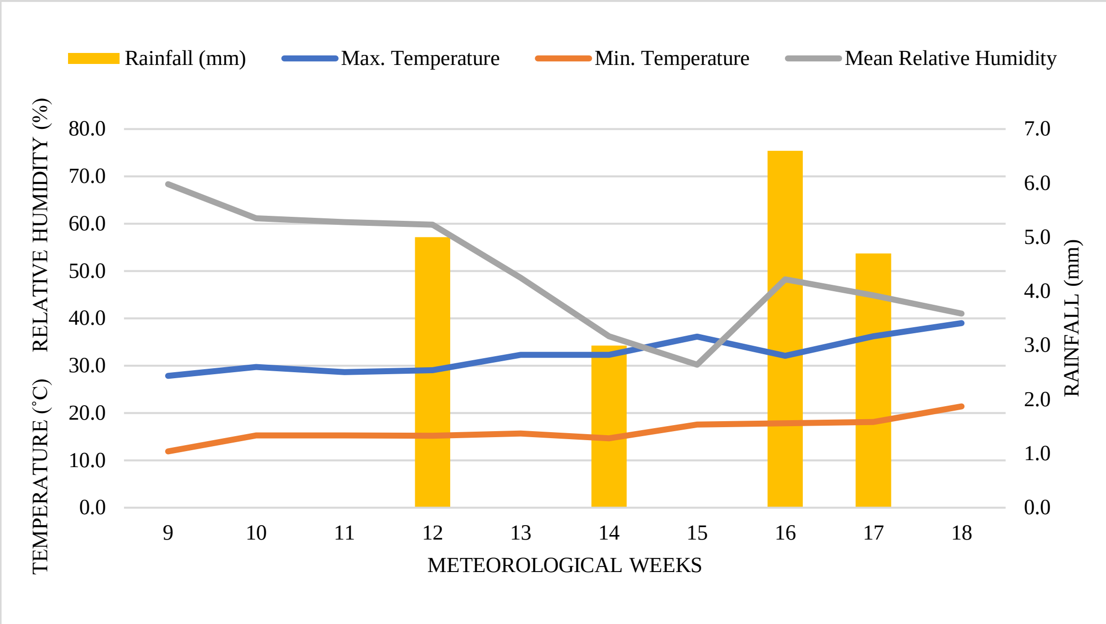

Fig 1: Meteorological data during February 26th (week 9) to 30th April (week 18)

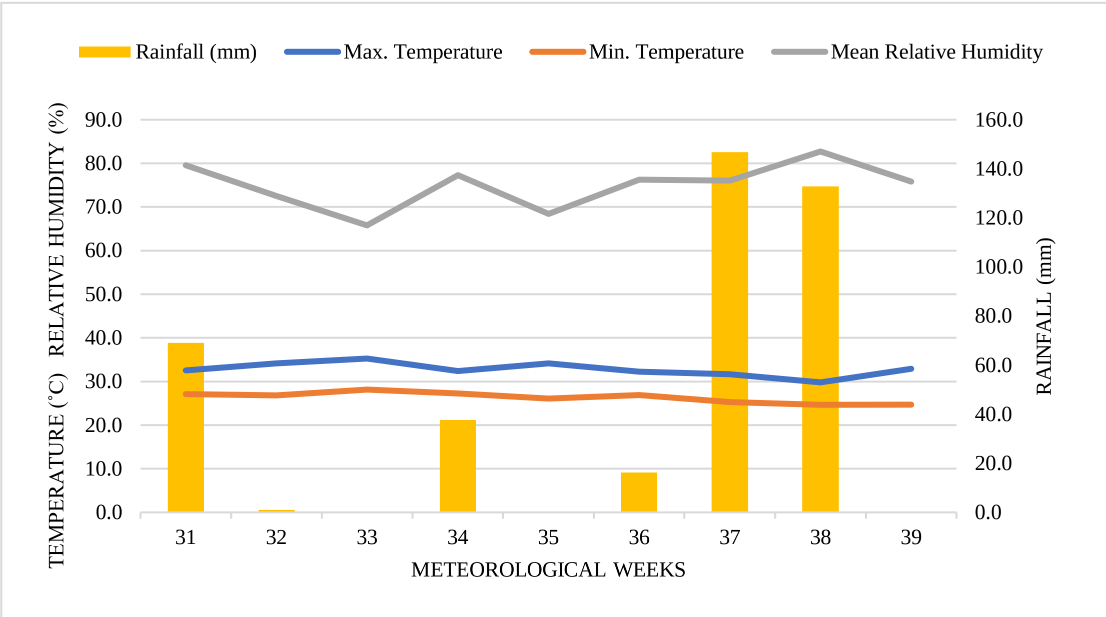

Fig 2: Meteorological data during 30th July (week 31) to 24th September (week 39)

Table 3.1: Physico-chemical properties of soil at different experimental locations

	pH	EC (m mhos cm^{-1})	Organic carbon (%)	P (kg ha^{-1})	K (kg ha^{-1})
			Winter season		
Location I	8.0	0.20	0.21	16.25	172.5
Location II	8.0	0.21	0.36	13.25	165.0
Location III	8.1	0.23	0.38	15.0	337.5
			Summer season		
Location IV	8.2	0.15	0.39	10.75	202.5
Location V	8.2	0.14	0.24	9.5	160.0
Location VI	8.3	0.11	0.27	11.0	155.0

3.3: Plan of work

The detail of present study is as below:

3.3.1: Name of the experiment

Effect of post-emergence herbicides on weed control in lawn (C*ynodon dactylon* L.) Selection No.1

3.3.2: Location of experiment

The experiment was conducted on six locations at PAU campus over well-established lawns.

3.3.3: Experimental Design

The experiment was laid out in Randomized Complete Block Design

Variety	:	*Cynodon dactylon* L. (Selection No.1)
Number of treatments	:	15
Number of locations	:	6
Number of replications	:	3
Total number of plots	:	45 at each location
Plot size	:	5m × 2m = 10 sq. m.

4. Treatments:

Table 3.2: Weed control treatments proposed in the experiment

Treatments	**Name of the herbicide***	**Dose kg ha^{-1} (a.i.)**
T1	Isoproturon	0.937
T2	Mesosulfuron + iodosulfuron	0.014
T3	Clodinafop + metribuzin	0.216
T4	2,4-D amine	0.500
T5	Bispyribac-sodium	0.025
T6	Metribuzin	0.120
T7	Metsulfuron-methyl	0.005
T8	Carfentrazone-ethyl	0.020
T9	Metsulfuron + carfentrazone-ethyl	0.025
T10	Metsulfuron-methyl + chlorimuron-ethyl	0.004
T11	Ethoxysulfuron	0.018
T12	Halosulfuron-methyl	0.050
T13	Atrazine	1.000
T14	Two hand weedings (at 15 days interval)	-
T15	Un-weeded (control)	-

*****The commercial doses of different herbicides have been provided in Annexure I

4.2: Time and method of herbicide application

The herbicides were applied on clear, sunny and calm day using Knapsack sprayer attached with flat fan nozzle. As per treatments the required quantity of herbicide was applied by dissolving in water @ 375 litre ha^{-1}.

5. Turfgrass species and duration of experiment

Cynodon dactylon cultivar Selection No. 1, a fine strain of Bermuda grass was used for the weed control experimental treatments and record of the observations. The detail of seasonality of the experiments conducted to check the emergence of winter weed flora began 1 March 2021 till 30 April 2021. Likewise, the second experiment to check the summer season weed growth began during 1 August 2021 till 30 September 2021.

6. Cultural practices

Lawn was mowed manually with a lawn mower (12 inches reel width) one month before application of different weed control treatments. Care was taken that the mowing height of grass was never kept shorter than 5 cm. The lawns were well established which were irrigated twice a week on hot dry months and once a week during winters. No irrigation was done during the monsoon. Urea was applied as drench at the rate 0.5 per cent at 30 days after the herbicide spray.

7. Observations recorded

The observations were recorded on the following aspects:

7.1: Weed characteristics

7.1.1: Species-wise weed density before and after herbicide spray (No. m^{-2})

Species-wise weed density was recorded at two fixed spots in each plot with the help of 50 cm × 50 cm quadrat before spray and at 15, 30, 45 and 60 days after spray (DAS). These weeds were identified and categorized as grass, broadleaf and sedges. The weed count was expressed as number m^{-2}. Species wise density of weeds that resprouted after weed control treatments and the density of newly emerged weed species in the experimental plots was recorded upto 60 DAS.

7.1.2: Fresh weight of weeds before spray

All the weeds retained in quadrat (50 cm × 50 cm) were cut from soil surfaces from above ground and collected in paper bags from every plot. The fresh weight of weeds was recorded with the help of electronic weighing balance and weight was expressed as g m^{-2}.

7.1.3: Dry weight of weeds 0, 15, 30, 45 and 60 days after the herbicide spray

The fresh weed plant samples were sun dried for 2-3 days before oven drying until the maximum loss of moisture was recorded. The samples were kept in the oven at 55°C till constant dry weight was achieved and final weight was recorded and was expressed as g m^{-2}.

7.1.4: Weed control efficiency (WCE %)

The weed control efficiency of different weed control treatments was worked out to know the percentage of weed reduction under the influence of different weed control treatments as below given formula (Mani *et al* 1976).

$$WCE\ (\%) = \frac{DMC\text{-}DMT}{DMC} \times 100$$

Where,

DMC = Dry matter production of weeds in un-weeded plot (control).

DMT = Dry matter production of weeds in treated plot.

7.2: Turfgrass characteristics

7.2.1: Height of sward before mowing

The sward height was measured with scale before mowing. The scale was aligned vertical and the height was measured from ground level to the tip of grass leaf blade, expressed in cm.

7.2.2: Visual colour ratings

The colour of the turf being a qualitative attribute, was observed visually. The scores (1-9) were rated to distinguish the various hues of green colour according to the fifth edition of Royal Horticultural Society Colour Chart (Voss, 2002). The turfgrass colour was rated as below:

Turfgrass colour	Colour rating
Yellow green	1
Olive green	2
Light green	3
Gray green	4
Luscious green	5
Green	6
Grassy green	7
Dirty green	8
Emerald	9

7.2.3: Turfgrass injury

Turfgrass injury ratings were recorded weekly using a scale of 1 - 9, where 9 was attributed as no injury and 1 as completely necrotic turf. A rating below 6.5 indicated unacceptable turfgrass injury, whereas a rating below 3.0 indicated severe injury (Meyer and Branham, 2006).

7.2.4: Fresh weight of grass clippings after mowing

The grass clippings from 1 m^2 were mowed from above ground and were collected in paper bags from every plot. The fresh weight of grass clippings was recorded with the help of electronic weighing balance and was expressed in g m^{-2}.

7.2.5: Dry weight of grass clippings after mowing

The grass clippings from 1 m^2 after mowing were collected in paper bags. The samples were sun dried for 2-3 days until maximum moisture loss was recorded. The samples were kept in the oven at 55°C till constant dry weight was achieved. The dry weight of grass clippings was expressed in g m^{-2}.

7.3: Phytotoxicity rating

Visual phytotoxicity rating was recorded at 3, 7, 10, 15 and 25 days after application of herbicidal treatments to know the extent of toxicity caused by different herbicides on *Cynodon dactylon* turf. The phytotoxicity rating (Table 3.3) was recorded using 0 to 10 scale, Rao (1986)

Table 3.3: Turf phytotoxicity rating (0 to 10 scale)

Effect	Score	Phytotoxicity symptoms
None	0	No injury, normal
	1	Slight stunting injury or discoloration
Slight	2	Some stand loss, stunting or discoloration
	3	Injury more pronounced but not persistent
	4	Moderate injury, recovery possible
Moderate	5	Injury more persistent, recovery possible
	6	Near severe injury, no recovery possible
	7	Sever injury, stand loss
Severe	8	Almost destroyed, a few plants surviving
	9	Very few plants alive
Complete	10	Complete destruction

8. Statistical analysis

Statistical analysis was carried out for the observations recorded in the experiment to find out any significant variation of different parameters among weed management methods. The data was subjected to square root transformation $\sqrt{x+1}$. Data were subjected to statistical analysis by Statistical Package for Social Sciences (SPSS) software Ver. 26.0. The comparisons were made at 5 per cent level of significance by using Tukey's test.

CHAPTER - IV

RESULTS AND DISCUSSION

The present investigations entitled "Effect of post-emergence herbicides on weed control in lawn (C*ynodon dactylon* L.) Selection No. 1" were conducted over well-established lawn at different locations during winter and summer season. Different post-emergence herbicides were evaluated for effective weed control in lawns. The results of the studies obtained are discussed below.

4.1: Winter season

Weed flora differ in different seasons and at different sites. The major weed flora among grasses was *Poa annua*; among broadleaf weeds were *Gnaphalium purpureum*, *Oxalis corniculata, Veronica agrestis, Desmodium triflorum, Coronopus didymus, Erigeron canadensis* and *Stellaria media*; among sedges was *Cyperus rotundus*. The density of grasses was 23.1 per cent, broadleaf was 71.1 per cent and sedges was 5.8 per cent.

Table 4.1.1: *Poa annua* density before herbicide spray at different locations in lawn during winter season

Treatments	*Poa annua* density (No. m^{-2}) before spray		
	Location I	Location II	Location III
Isoproturon	122	39	61
Mesosulfuron + Iodosulfuron	117	44	50
Clodinafop + Metribuzin	106	33	56
2,4-D amine	117	33	50
Bispyribac sodium	106	39	50
Metribuzin	122	44	61
Metsulfuron	133	39	56
Carfentrazone-ethyl	117	39	56
Metsulfuron + Carfentrazone-ethyl	100	44	61
Metsulfuron-methyl + Chlorimuron-ethyl	111	33	67
Ethoxysulfuron	128	44	56
Halosulfuron	133	39	56
Atrazine	128	44	44
Two hand weedings (15 days interval)	106	39	61
Un-weeded (control)	117	44	61

4.1.1: *Poa annua* density

Poa annua density before the herbicide spray at different locations in Table 4.1.1. The number of plants of *Poa annua* ranged between 100 - 133 m^{-2} at Location I whereas this range was 33 to 44 m^{-2} and 44 to 67 m^{-2} at Location II and Location III, respectively. The *Poa annua* density difference was non-significant at all the locations as the density was recorded before the spray of different herbicides.

The weed mortality indicates the comparative efficacy of a particular herbicide. *Poa annua* density as recorded 15 DAS of different post-emergence herbicides are presented in Table 4.1.2. The density of *Poa annua* indicated that isoproturon @ 0.937 kg ha^{-1}, mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1}, clodinafop + metribuzin @ 0.216 kg ha^{-1}, bispyribac sodium @ 0.025 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, ethoxysulfuron @ 0.018 kg ha^{-1} and hand weeding provided complete control of this weed which was significantly less as compared with all other herbicides and weedy check at all the locations. McAfee and Baumann (2007) also reported that metribuzin is used to control grass weeds. No new emergence of this weed was observed after 15 DAS due change in temperature (Annexure II).

Table 4.1.2: Effect of post-emergence herbicides on *Poa annua* density at different locations 15 days after spray (DAS) in lawn

Treatments	**Dose (kg ha^{-1})**	***Poa annua* density (No. m^{-2}) at 15 DAS**		
		Location I	Location II	Location III
Isoproturon	0.937	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Mesosulfuron + Iodosulfuron	0.014	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Clodinafop + Metribuzin	0.216	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
2,4-D amine	0.500	9.17^{b} (83)	5.35^{bc} (28)	6.73^{bc} (44)
Bispyribac sodium	0.025	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metribuzin	0.120	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron	0.005	10.31^{c} 106)	5.35^{bc} (28)	6.73^{bc} (44)
Carfentrazone-ethyl	0.020	10.34^{c} (108)	5.35^{bc} (28)	6.73^{bc} (44)
Metsulfuron + Carfentrazone-ethyl	0.025	10.31^{c} (106)	5.53^{bcd} (30)	7.16^{c} (50)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	10.31^{c} (106)	5.35^{bc} (28)	7.00^{c} (48)
Ethoxysulfuron	0.018	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Halosulfuron	0.050	8.22^{b} (67)	4.81^{b} (22)	5.85^{b} (33)
Atrazine	1.000	9.17^{b} (83)	5.85^{cd} (33)	5.85^{b} (33)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	10.31^{c} (105)	6.30^{d} (39)	7.16^{c} (50)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.1.2: *Gnaphalium purpureum* density

Gnaphalium purpureum density before herbicide spray was ranged between 22 to 33 m^{-2} at Location I whereas this range was 28 to 39 m^{-2} at Location II and 44 to 67 m^{-2} at Location III (Table 4.1.3.). *Gnaphalium purpureum* density difference was non-significant at all the locations as the density was recorded before the spray of post-emergence herbicides.

Gnaphalium purpureum density recorded at 15 and 30 DAS indicated that hand weeded at 15 DAS provided complete control of this weed and recorded significantly lower *G. purpureum* density as compared to herbicides and weedy check (Table 4.1.4.). Whereas, two hand weedings, isoproturon @ 0.937 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1}, metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and atrazine @ 1.0 kg ha^{-1} provided complete control at 30 DAS at all the locations. McAfee and Baumann (2007) also reported that post-emergence herbicides viz; atrazine, carfentrazone, and metsulfuron-methyl controlled broadleaf weed.

The density at 45 and 60 DAS (Table 4.1.5.) revealed that two hand weedings, isoproturon @ 0.937 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1}, metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and atrazine @ 1.0 kg ha^{-1} provided complete control upto 60 DAS at all the locations and significantly less as compared with weedy check and rest of the herbicides during winter season.

Table 4.1.3: *Gnaphalium purpureum* Density before herbicide spray at different locations in lawn during winter season

Treatments	***G. purpureum* density (No. m^{-2}) before spray**		
	Location I	Location II	Location III
Isoproturon	28	33	44
Mesosulfuron + Iodosulfuron	28	33	67
Clodinafop + Metribuzin	33	28	61
2,4-D amine	28	28	50
Bispyribac sodium	28	28	44
Metribuzin	28	28	61
Metsulfuron	28	33	61
Carfentrazone-ethyl	28	39	44
Metsulfuron + Carfentrazone-ethyl	28	39	50
Metsulfuron-methyl + Chlorimuron-ethyl	33	28	50
Ethoxysulfuron	28	39	61
Halosulfuron	33	28	44
Atrazine	22	33	67
Two hand weedings (15 days interval)	33	28	78
Un-weeded (control)	33	28	61

Before spray

15 DAS

Plate 1: Effect of isoproturon spray on *Poa annua*

Before spray

20 DAS

Plate 2: Effect of metsulfuron + carfentrazone-ethyl spray on *Gnaphalium purpureum*

Table 4.1.4: Effect of post-emergence herbicides on periodic *Gnaphalium purpureum* density at different locations 15 and 30 DAS in lawn

Treatments	Dose (kg ha^{-1})	*G. purpureum* density (No. m^{-2})					
		15 DAS			30 DAS		
		Location I	Location II	Location III	Location I	Location II	Location III
Isoproturon	0.937	4.16^{b} (17)	3.47^{ab} (11)	4.82^{ab} (22)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Mesosulfuron + Iodosulfuron	0.014	4.81^{bc} (22)	4.81^{bcd} (22)	7.52^{c} (56)	4.81^{bc} (22)	4.81^{bc} (22)	7.52^{c} (56)
Clodinafop + Metribuzin	0.216	4.16^{b} (17)	4.16^{b} (17)	6.74^{bc} (44)	4.16^{b} (17)	4.16^{b} (17)	6.74^{bc} (44)
2,4-D amine	0.500	5.34^{bc} (28)	5.35^{cd} (28)	7.14^{bc} (50)	5.34^{cd} (28)	5.35^{bc} (28)	7.14^{bc} (50)
Bispyribac sodium	0.025	5.34^{bc} (28)	5.35^{cd} (28)	6.74^{bc} (44)	5.34^{cd} (28)	5.35^{bc} (28)	6.74^{bc} (44)
Metribuzin	0.120	4.16^{b} (17)	4.16^{bc} (17)	6.74^{bc} (44)	4.16^{b} (17)	4.16^{b} (17)	6.74^{bc} (44)
Metsulfuron	0.005	4.16^{b} (17)	4.16^{bc} (17)	4.82^{ab} (22)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Carfentrazone-ethyl	0.020	4.16^{b} (17)	4.16^{b} (17)	4.82^{ab} (22)	4.16^{b} (17)	4.16^{b} (17)	4.82^{ab} (22)
Metsulfuron + Carfentrazone-ethyl	0.025	4.16^{b} (17)	4.81^{bcd} (22)	4.82^{ab} (22)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	4.16^{b} (17)	4.81^{bcd} (22)	6.32^{bc} (39)	4.16^{b} (17)	4.81^{bc} (22)	6.32^{bc} (39)
Ethoxysulfuron	0.018	4.81^{bc} (22)	5.85^{d} (33)	7.14^{bc} (50)	4.81^{bc} (22)	5.85^{c} (33)	7.14^{bc} (50)
Halosulfuron	0.050	5.85^{c} (33)	5.35^{cd} (28)	6.74^{bc} (44)	5.85^{d} (33)	5.35^{bc} (28)	6.74^{bc} (44)
Atrazine	1.000	4.81^{bc} (22)	4.16^{b} (17)	4.82^{ab} (22)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	5.85^{c} (33)	5.35^{cd} (28)	7.88^{c} (61)	5.85^{d} (33)	5.35^{bc} (28)	7.88^{c} (61)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

Table 4.1.5: Effect of post-emergence herbicides on periodic *Gnaphalium purpureum* density at different locations 45 and 60 DAS in lawn

Treatments	Dose (kg ha^{-1})	*G. purpureum* density (No. m^{-2})					
		45 DAS			60 DAS		
		Location I	Location II	Location III	Location I	Location II	Location III
Isoproturon	0.937	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Mesosulfuron + Iodosulfuron	0.014	4.81^{bc} (22)	4.81^{bc} (22)	7.52^{c} (56)	4.81^{bc} (22)	4.81^{bc} (22)	7.52^{c} (56)
Clodinafop + Metribuzin	0.216	4.16^{b} (17)	4.16^{b} (17)	6.74^{bc} (44)	4.16^{b} (17)	4.16^{b} (17)	6.74^{bc} (44)
2,4-D amine	0.500	5.34^{cd} (28)	5.35^{bc} (28)	7.14^{bc} (50)	5.34^{cd} (28)	5.35^{bc} (28)	7.14^{bc} (50)
Bispyribac sodium	0.025	5.34^{cd} (28)	5.35^{bc} (28)	6.74^{bc} (44)	5.34^{cd} (28)	5.35^{bc} (28)	6.74^{bc} (44)
Metribuzin	0.120	4.16^{b} (17)	4.16^{b} (17)	6.74^{bc} (44)	4.16^{b} (17)	4.16^{b} (17)	6.74^{bc} (44)
Metsulfuron	0.005	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Carfentrazone-ethyl	0.020	4.16^{b} (17)	4.16^{b} (17)	4.82^{ab} (22)	4.16^{b} (17)	4.16^{b} (17)	4.82^{ab} (22)
Metsulfuron + Carfentrazone-ethyl	0.025	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	4.16^{b} (17)	4.81^{bc} (22)	6.32^{bc} (39)	4.16^{b} (17)	4.81^{bc} (22)	6.32^{bc} (39)
Ethoxysulfuron	0.018	4.81^{bc} (22)	5.85^{c} (33)	7.14^{bc} (50)	4.81^{bc} (22)	5.85^{c} (33)	7.14^{bc} (50)
Halosulfuron	0.050	5.85^{d} (33)	5.35^{bc} (28)	6.74^{bc} (44)	5.85^{d} (33)	5.35^{bc} (28)	6.74^{bc} (44)
Atrazine	1.000	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	5.85^{d} (33)	5.35^{bc} (28)	7.88^{c} (61)	5.85^{d} (33)	5.35^{bc} (28)	7.88^{c} (61)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

Table 4.1.6: *Oxalis corniculata* density before spray of post-emergence herbicides at different locations in lawn during winter season

Treatments	*Oxalis corniculata* density (No. m^{-2}) before spray		
	Location I	Location II	Location III
Isoproturon	106	89	50
Mesosulfuron + Iodosulfuron	100	83	50
Clodinafop + Metribuzin	106	78	61
2,4-D amine	100	78	56
Bispyribac sodium	94	78	44
Metribuzin	89	94	50
Metsulfuron	94	83	72
Carfentrazone-ethyl	117	94	72
Metsulfuron + Carfentrazone-ethyl	100	94	44
Metsulfuron-methyl + Chlorimuron-ethyl	111	83	56
Ethoxysulfuron	117	78	50
Halosulfuron	94	78	67
Atrazine	94	100	56
Two hand weedings (15 days interval)	100	94	50
Un-weeded (control)	94	83	67

4.1.3: *Oxalis corniculata* density

Oxalis corniculata density before the spray of herbicides ranged between 89 to 117 m^{-2} at Location I whereas this range was 78 to 100 m^{-2} and 44 to 72 m^{-2} at Location II and Location III, respectively (Table 4.1.6.). The *Oxalis corniculata* density difference was non-significant at all the locations as the density was recorded before the spray of post-emergence herbicides during winter season.

Oxalis corniculata density as recorded 15 and 30 days after the application of different herbicides are presented in Table 4.1.7. At 15 DAS, *Oxalis corniculata* density was recorded less metsulfuron @ 0.005 kg ha^{-1}, carfentrazone-ethyl @ 0.020 kg ha^{-1} and metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and was at par with hand weeding. At 30 DAS, clodinafop + metribuzin @ 0.216 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and hand weeded provided complete control of this weed which was significantly lower as compared with all other weed control treatments and unweeded control at all the locations in lawn.

The density of *Oxalis corniculata* when observed at 45 and 60 DAS revealed that only metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} provided complete control upto 60 DAS at all locations. There was new emergence of *Oxalis corniculata* in clodinafop + metribuzin @ 0.216 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1} and two hand weedings.

Table 4.1.7: Effect of post-emergence herbicides on periodic *Oxalis corniculata* density at different locations 15 and 30 DAS in lawn

Treatments	Dose (kg ha^{-1})	*Oxalis corniculata* density (No. m^{-2})					
		15 DAS			30 DAS		
		Location I	Location II	Location III	Location I	Location II	Location III
Isoproturon	0.937	7.13^{b} (50)	6.30^{bc} (39)	5.36^{bc} (28)	7.13^{b} (50)	6.30^{bc} (39)	5.36^{bc} (28)
Mesosulfuron + Iodosulfuron	0.014	9.69^{c} (94)	8.87^{d} (78)	6.74^{cd} (44)	9.69^{c} (94)	8.87^{d} (79)	6.74^{c} (44)
Clodinafop + Metribuzin	0.216	5.34^{ab} (28)	4.81^{ab} (22)	4.82^{abc} (22)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
2,4-D amine	0.500	9.46^{c} (89)	7.88^{cd} (61)	6.74^{cd} (44)	9.46^{c} (89)	7.88^{cd} (61)	6.74^{c} (44)
Bispyribac sodium	0.025	9.69^{c} (94)	8.87^{d} (78)	6.74^{cd} (44)	9.69^{c} (94)	8.87^{d} (78)	6.74^{c} (44)
Metribuzin	0.120	5.34^{ab} (28)	4.81^{ab} (22)	4.82^{abc} (22)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron	0.005	4.16^{a} (17)	3.47^{a} (11)	4.19^{ab} (17)	4.19^{ab} (17)	3.47^{a} (11)	4.19^{ab} (17)
Carfentrazone-ethyl	0.020	4.81^{ab} (22)	4.19^{ab} (17)	4.19^{ab} (17)	4.81^{ab} (22)	4.19^{ab} (17)	4.19^{ab} (17)
Metsulfuron + Carfentrazone-ethyl	0.025	4.16^{a} (17)	4.19^{ab} (17)	3.48^{ab} (11)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	4.81^{ab} (22)	4.19^{ab} (17)	4.82^{abc} (22)	4.81^{ab} (22)	4.19^{ab} (17)	4.82^{b} (22)
Ethoxysulfuron	0.018	10.57^{c} (111)	8.55^{d} (72)	6.74^{cd} (44)	10.57^{c} (111)	8.55^{d} (72)	6.74^{c} (44)
Halosulfuron	0.050	9.69^{c} (94)	8.87^{d} (78)	8.23^{d} (67)	9.69^{c} (94)	8.87^{d} (78)	8.23^{d} (67)
Atrazine	1.000	7.13^{b} (50)	6.30^{bc} (39)	5.36^{bc} (28)	7.13^{b} (50)	6.30^{bc} (39)	5.36^{bc} (28)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	9.69^{c} (94)	9.18^{d} (83)	8.23^{d} (67)	9.69^{c} (94)	9.18^{d} (83)	8.23^{d} (67)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

Table 4.1.8: Effect of post-emergence herbicides on *Oxalis corniculata* periodic density at different locations 45 and 60 DAS in lawn

Treatments	Dose (kg ha^{-1})	*Oxalis corniculata* density (No. m^{-2})					
		45 DAS			60 DAS		
		Location I	Location II	Location III	Location I	Location II	Location III
Isoproturon	0.937	7.13^{b} (50)	6.30^{bc} (39)	5.36^{bc} (28)	7.87^{cd} (61)	6.74^{cd} (44)	5.86^{bcd} (33)
Mesosulfuron + Iodosulfuron	0.014	9.69^{c} (94)	8.87^{d} (79)	6.74^{c} (44)	10.10^{d} (100)	9.17^{e} (83)	7.14^{cde} (50)
Clodinafop + Metribuzin	0.216	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	5.34^{ab} (28)	4.81^{abc} (22)	4.82^{ab} (22)
2,4-D amine	0.500	9.46^{c} (89)	7.88^{cd} (61)	6.74^{c} (44)	9.46^{cd} (89)	7.88^{de} (61)	6.74^{bcde} (44)
Bispyribac sodium	0.025	9.69^{c} (94)	8.87^{d} (78)	6.74^{c} (44)	9.69^{d} (94)	8.87^{e} (78)	7.52^{de} (56)
Metribuzin	0.120	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	5.34^{ab} (28)	4.81^{abc} (22)	4.82^{ab} (22)
Metsulfuron	0.005	4.19^{ab} (17)	3.47^{a} (11)	4.19^{ab} (17)	4.81^{ab} (22)	4.16^{ab} (17)	4.82^{ab} (22)
Carfentrazone-ethyl	0.020	4.81^{ab} (22)	4.19^{ab} (17)	4.19^{ab} (17)	5.34^{ab} (28)	4.81^{abc} (22)	5.34^{bc} (28)
Metsulfuron + Carfentrazone-ethyl	0.025	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	4.81^{ab} (22)	4.19^{ab} (17)	4.82^{b} (22)	5.85^{bc} (33)	4.81^{abc} (22)	5.86^{bcd} (33)
Ethoxysulfuron	0.018	10.57^{c} (111)	8.55^{d} (72)	6.74^{c} (44)	10.57^{d} (111)	8.55^{e} (72)	6.74^{bcde} (44)
Halosulfuron	0.050	9.69^{c} (94)	8.87^{d} (78)	8.23^{d} (67)	9.69^{d} (94)	8.87^{e} (78)	8.23^{e} (67)
Atrazine	1.000	7.13^{b} (50)	6.30^{bc} (39)	5.36^{bc} (28)	7.13^{bc} (50)	6.30^{bcd} (39)	6.32^{bcd} (39)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	5.34^{ab} (28)	6.30^{bcd} (39)	5.34^{bc} (28)
Un-weeded (control)	-	9.69^{c} (94)	9.18^{d} (83)	8.23^{d} (67)	9.69^{d} (94)	9.18^{e} (83)	8.23^{e} (67)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

Table 4.1.9: *Veronica agrestis* density before spray of post-emergence herbicides at different locations in lawn during winter season

Treatments	*V. agrestis* density (No. m^{-2}) before spray		
	Location I	Location II	Location III
Isoproturon	44	17	67
Mesosulfuron + Iodosulfuron	39	28	44
Clodinafop + Metribuzin	50	22	56
2,4-D amine	39	28	50
Bispyribac sodium	50	28	56
Metribuzin	39	17	61
Metsulfuron	50	28	56
Carfentrazone-ethyl	39	28	61
Metsulfuron + Carfentrazone-ethyl	44	22	56
Metsulfuron-methyl + Chlorimuron-ethyl	44	17	50
Ethoxysulfuron	39	22	44
Halosulfuron	50	22	61
Atrazine	44	17	56
Two hand weedings (15 days interval)	50	28	78
Un-weeded (control)	50	28	56

Table 4.1.10: Effect of post-emergence herbicides on *Veronica agrestis* density at different locations 15 DAS in lawn

Treatments	Dose (kg ha^{-1})	*V. agrestis* density (No. m^{-2}) at 15 DAS		
		Location I	Location II	Location III
Isoproturon	0.937	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Mesosulfuron + Iodosulfuron	0.014	5.34^{c} (28)	4.81^{b} (22)	5.85^{b} (33)
Clodinafop + Metribuzin	0.216	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
2,4-D amine	0.500	4.16^{b} (17)	4.19^{b} (17)	4.19^{ab} (17)
Bispyribac sodium	0.025	7.13^{d} (50)	5.35^{b} (28)	7.52^{c} (56)
Metribuzin	0.120	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron	0.005	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Carfentrazone-ethyl	0.020	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron + Carfentrazone-ethyl	0.025	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Ethoxysulfuron	0.018	5.34^{c} (28)	4.16^{b} (17)	5.85^{b} (33)
Halosulfuron	0.050	6.71^{d} (44)	4.16^{b} (17)	7.52^{c} (56)
Atrazine	1.000	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	7.13^{d} (50)	5.35^{b} (28)	7.52^{c} (56)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.1.4: *Veronica agrestis* density

Veronica agrestis density before the spray of post-emergence herbicides at different locations are presented in Table 4.1.9. The number of plants of *Veronica agrestis* ranged between 39 to 50 m^{-2} at Location I whereas this range was 17 to 28 m^{-2} at Location II and 44 to 78 m^{-2} at Location III. *Veronica agrestis* density difference was non-significant at all the locations as the density was recorded before the application of different herbicide treatments.

The density of *Veronica agrestis* as influenced by different weed control treatments as presented in Table 4.1.10 as observed 15 days after the application of different post-emergence herbicides showed that isoproturon @ 0.937 kg ha^{-1}, clodinafop + metribuzin @ 0.216 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1}, carfentrazone-ethyl @ 0.020 kg ha^{-1} and metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1}, metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1}, atrazine @ 1 kg ha^{-1} and hand weeding provided complete control, which was significantly less as compared with all other weed control treatments and weedy check at all the locations. 2,4-D amine @ 0.5 kg ha^{-1} proved to be the second-best herbicide for the control of this weed. Sharma and Sharma (1997) also reported similar findings of an experiment as effective control of all broadleaf weeds with the use of metsulfuron methyl @ 0.004 kg ha^{-1}.

4.1.5: *Desmodium triflorum* density

Desmodium triflorum density before and after the application of herbicides at location I are presented in Table 4.1.11. The number of plants of *Desmodium triflorum* ranged between 44 to 56 m^{-2} at Location I however, this weed did not appear at other locations. *Desmodium triflorum* density difference was non-significant as the density was recorded before the spray of post-emergence herbicides.

The density of *Desmodium triflorum* as recorded at 15 DAS showed the lowest weed density in hand weeding which was significantly lower than all other herbicide treatments and unweeded check. At 30 DAS, minimum weed density was recorded in clodinafop + metribuzin @ 0.216 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1}, metsulfuron + chlorimuron-ethyl @ 0.004 kg ha^{-1}. Metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and two hand weeding provided complete control when observed upto 60 DAS and was significantly lower as compared with all other weed control treatments and weedy check. This weed did not appear at other locations.

Table 4.1.11: *Desmodium triflorum* density before and after the spray of post-emergence herbicides at Location I in lawn during winter season

Treatments	Dose ($kg\ ha^{-1}$)	*Desmodium triflorum* density ($No.\ m^{-2}$)				
		Before spray	15 DAS	30 DAS	45 DAS	60 DAS
Isoproturon	0.937	44	7.13[bc] (50)	7.74[bc] (61)	9.27[c] (89)	9.44[c] (89)
Mesosulfuron + Iodosulfuron	0.014	50	7.13[bc] (50)	7.13[bc] (50)	7.88[bc] (61)	7.88[bc] (61)
Clodinafop + Metribuzin	0.216	50	6.31[bc] (39)	6.31[b] (39)	6.31[b] (39)	6.31[b] (39)
2,4-D amine	0.500	54	6.71[bc] (44)	6.71[bc] (44)	7.50[bc] (56)	7.50[bc] (56)
Bispyribac sodium	0.025	55	7.88[cd] (61)	7.88[bc] (61)	7.88[bc] (61)	7.88[bc] (61)
Metribuzin	0.120	50	6.31[bc] (39)	6.31[b] (39)	6.31[b] (39)	6.75[b] (44)
Metsulfuron	0.005	56	6.74[bc] (44)	6.31[b] (39)	6.74[b] (44)	8.23[bc] (67)
Carfentrazone-ethyl	0.020	50	6.74[bc] (44)	7.13[bc] (50)	7.13[bc] (50)	7.52[bc] (56)
Metsulfuron + Carfentrazone-ethyl	0.025	49	6.31[bc] (39)	1.00[a] (0)	1.00[a] (0)	1.00[a] (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	44	6.31[bc] (39)	6.31[b] (39)	6.31[b] (39)	6.75[b] (44)
Ethoxysulfuron	0.018	50	7.13[bc] (50)	7.13[bc] (50)	7.13[bc] (50)	7.52[bc] (55)
Halosulfuron	0.050	44	6.75[bc] (44)	6.75[bc] (44)	6.75[b] (44)	7.13[bc] (50)
Atrazine	1.000	56	6.31[bc] (39)	7.13[bc] (50)	7.13[bc] (50)	7.13[bc] (50)
Two hand weedings (15 days interval)	-	51	1.00[a] (0)	1.00[a] (0)	1.00[a] (0)	1.00[a] (0)
Un-weeded (control)	-	50	8.82[d] (78)	8.82[c] (78)	9.44[c] (89)	9.44[c] (89)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

Table 4.1.12: *Coronopus didymus* density before and after the spray of post-emergence herbicides at Location II in lawn during winter season

Treatments	Dose (kg ha^{-1})	*Coronopus didymus* density (No. m^{-2})				
		Before spray	15 DAS	30 DAS	45 DAS	60 DAS
Isoproturon	0.937	83	7.88^{e} (61)	5.85^{c} (33)	5.85^{c} (33)	5.85^{c} (33)
Mesosulfuron + Iodosulfuron	0.014	89	5.85^{bcd} (33)	5.85^{c} (33)	5.85^{c} (33)	5.85^{c} (33)
Clodinafop + Metribuzin	0.216	106	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
2,4-D amine	0.500	89	6.30^{cde} (39)	3.47^{ab} (11)	3.47^{ab} (11)	3.47^{ab} (11)
Bispyribac sodium	0.025	100	9.48^{f} (89)	9.48^{e} (89)	9.48^{e} (89)	9.48^{e} (89)
Metribuzin	0.120	94	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron	0.005	83	3.47^{ab} (11)	3.47^{ab} (11)	3.47^{ab} (11)	3.47^{ab} (11)
Carfentrazone-ethyl	0.020	106	4.19^{abc} (17)	4.19^{abc} (17)	4.19^{abc} (17)	4.19^{abc} (17)
Metsulfuron + Carfentrazone-ethyl	0.025	89	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	89	5.35^{bc} (28)	5.35^{bc} (28)	5.35^{bc} (28)	5.35^{bc} (28)
Ethoxysulfuron	0.018	94	7.88^{e} (61)	7.88^{d} (61)	7.88^{d} (61)	7.88^{d} (61)
Halosulfuron	0.050	89	7.51^{de} (56)	7.51^{d} (56)	7.51^{d} (56)	7.51^{d} (56)
Atrazine	1.000	83	4.19^{abc} (17)	4.19^{abc} (17)	4.19^{abc} (17)	4.19^{abc} (17)
Two hand weedings (15 days interval)	-	83	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	89	9.48^{f} (89)	9.48^{e} (89)	9.48^{e} (89)	9.48^{e} (89)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.1.6: *Coronopus didymus* density

Coronopus didymus density before the spray of herbicides are presented in Table 4.1.12. The number of plants of *Coronopus didymus* ranged between 83 to 106 m^{-2} at Location II however, this weed did not appear at other locations. *Coronopus didymus* density was non-significant as the density was recorded before the herbicide spray. At 15 DAS, lowest weed density recorded in clodinafop + metribuzin @ 0.216 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and hand weeding treatment which were

	
Before spray	20 DAS

Plate 3: Effect of metsulfuron + carfentrazone-ethyl spray on *Oxalis corniculata*

	
Before spray	15 DAS

Plate 4: Effect of metsulfuron + carfentrazone-ethyl spray on *Coronopus didymus*

significantly lower as compared with weedy check and other herbicides and controlled upto 60 DAS effectively. Isoproturon @ 0.937 kg, mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1}, 2,4-D amine @ 0.5 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1}, carfentrazone-ethyl @ 0.020 kg ha^{-1}, metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1} and atrazine @ 1 kg ha^{-1} also helped to reduce the population of this weed as compared with weedy check. The effect of 2,4-D amine @ 0.5 kg ha^{-1} after 30 DAS proved to reduce significantly the weed density when observed upto 60 DAS as compared with the weedy check.

Table 4.1.13: *Erigeron canadensis* density before and after the spray of post-emergence herbicides at Location II in lawn during winter season

Treatments	Dose (kg ha^{-1})	***Erigeron canadensis* density (No. m^{-2})**				
		Before spray	15 DAS	30 DAS	45DAS	60 DAS
Isoproturon	0.937	17	3.47^{b} (11)	4.19^{cd} (17)	4.19^{cd} (17)	5.35^{c} (28)
Mesosulfuron + Iodosulfuron	0.014	22	4.81^{c} (22)	4.81^{d} (22)	4.81^{d} (22)	5.35^{c} (28)
Clodinafop + Metribuzin	0.216	17	3.47^{b} (11)	4.19^{cd} (17)	4.19^{cd} (17)	5.35^{c} (28)
2,4-D amine	0.500	22	3.47^{b} (11)	4.19^{cd} (17)	4.19^{cd} (17)	5.35^{c} (28)
Bispyribac sodium	0.025	22	4.81^{c} (22)	4.81^{d} (22)	4.81^{d} (22)	5.35^{c} (28)
Metribuzin	0.120	17	3.47^{b} (11)	3.47^{bc} (11)	3.47^{bc} (11)	4.16^{abc} (17)
Metsulfuron	0.005	22	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	3.47^{ab} (11)
Carfentrazone-ethyl	0.020	17	3.47^{b} (11)	2.54^{ab} (6)	2.54^{ab} (6)	4.81^{bc} (22)
Metsulfuron + Carfentrazone-ethyl	0.025	17	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	22	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	3.47^{ab} (11)
Ethoxysulfuron	0.018	22	4.81^{c} (22)	4.81^{d} (22)	4.81^{d} (22)	5.35^{c} (28)
Halosulfuron	0.050	17	4.81^{c} (22)	4.81^{d} (22)	4.81^{d} (22)	5.35^{c} (28)
Atrazine	1.000	17	4.19^{bc} (17)	4.81^{d} (22)	4.81^{d} (22)	5.35^{c} (28)
Two hand weedings (15 days interval)	-	28	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	3.47^{ab} (11)
Un-weeded (control)	-	22	4.81^{c} (22)	4.81^{d} (22)	4.81^{d} (22)	5.35^{c} (28)

*Values in the parentheses are original means. Data was subjected to square root transformation √(x+1)

4.1.7: *Erigeron canadensis* density

Erigeron canadensis density before and after the application of herbicides spray at Location II are presented in Table 4.1.13. The number of plants of *Erigeron canadensis* ranged between 17 to 28 m^{-2} at Location II however this weed did not appear at other locations. The difference in the density was non-significant before the spray of post-emergence herbicides.

The density of *Erigeron canadensis* as recorded 15, 30, 45 and 60 DAS as presented in Table 4.1.13 revealed that when the observation was taken at 15 DAS, metsulfuron @ 0.005 kg ha^{-1}, metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1}, metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1} and hand weeding treatment effectively controlled *Erigeron canadensis* and the values were significantly lower as compared with all other weed control treatments and weedy check. Isoproturon @ 0.937 kg ha^{-1}, clodinafop + metribuzin @ 0.216 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, carfentrazone-ethyl @ 0.020 kg ha^{-1}, metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1} and atrazine @ 1.000 kg ha^{-1} were also observed to reduce the population of this weed as compared with weedy check. This weed remained suppressed upto 45 DAS and showed re-sprouting when observed at 60 DAS among all these treatments whereas metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} provided complete control upto 60 DAS during winter season.

Table 4.1.14: *Stellaria media* density before and after the spray of post-emergence herbicides at Location III in lawn

Treatments	Dose (kg ha^{-1})	*Stellaria media* density (No. m^{-2})	
		Before spray	15 DAS
Isoproturon	0.937	44	4.19^{ab} (17)
Mesosulfuron + Iodosulfuron	0.014	56	6.30^{c} (39)
Clodinafop + Metribuzin	0.216	44	4.19^{ab} (17)
2,4-D amine	0.500	50	1.00^{a} (0)
Bispyribac sodium	0.025	67	7.88^{d} (61)
Metribuzin	0.120	56	4.19^{ab} (17)
Metsulfuron	0.005	44	1.00^{a} (0)
Carfentrazone-ethyl	0.020	56	1.00^{a} (0)
Metsulfuron + Carfentrazone-ethyl	0.025	56	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	44	1.00^{a} (0)
Ethoxysulfuron	0.018	39	5.34^{bc} (28)
Halosulfuron	0.050	61	6.30^{c} (39)
Atrazine	1.000	39	1.00^{a} (0)
Two hand weedings (15 days interval)	-	61	1.00^{a} (0)
Un-weeded (control)	-	61	7.88^{d} (61)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.1.8: *Stellaria media* density

Stellaria media density before and after the spray of post-emergence herbicides at location III during winter season are presented in Table 4.1.14. The number of plants of *Stellaria media* ranged between 39 to 67 m^{-2} whereas at other locations this weed did not appear. *Stellaria media* density difference was non-significant before the application of herbicide treatments. At 15 DAS, 2,4-D amine @ 0.5 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1}, carfentrazone-ethyl @ 0.020 kg ha^{-1}, metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1}, metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1}, atrazine @ 1 kg ha^{-1} and hand weeding provided complete control of this weed and were significantly lower as compared with all other herbicide treatments and weedy check. Isoproturon @ 0.937 kg ha^{-1}, clodinafop + metribuzin @ 0.216 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1} were also helped to reduce the population of *Stellaria media* which was significantly better than weedy check and no re-sprouting of this weed was observed after 15 days.

4.1.9: *Cyperus rotundus* density

The number of plants of *Cyperus rotundus* ranged between 44 to 67 m^{-2} at Location I (Table 4.1.15.) however, this weed did not appear at other locations. The difference in the density of *Cyperus rotundus* was non-significant as the density was recorded before the spray of post-emergence herbicides during winter season.

The density of *Cyperus rotundus* as recorded at 15 DAS showed the lowest weed density in ethoxysulfuron @ 0.018 kg ha^{-1}, halosulfuron @ 0.050 kg ha^{-1} and hand weeding which was significantly lower than all other herbicide treatments and unweeded check. 2,4-D amine @ 0.5 kg ha^{-1} proved to be the second-best herbicide for the control of this weed. Halosulfuron @ 0.050 kg ha^{-1} provided complete control upto 45 DAS and resprouted when observed at 60 DAS whereas re-sprouting in ethoxysulfuron @ 0.018 kg ha^{-1} and two hand weedings when observed at 45 DAS.

Table 4.1.15: *Cyperus rotundus* density before and after the spray of post-emergence herbicides at Location I in lawn during winter season

Treatments	Dose (kg ha^{-1})	*Cyperus rotundus* density (No. m^{-2})				
		Before spray	15 DAS	30 DAS	45 DAS	60 DAS
Isoproturon	0.937	61	8.23[bc] (67)	8.86[bcd] (78)	9.77[cd] (94)	11.09[c] (122)
Mesosulfuron + Iodosulfuron	0.014	56	7.88[bc] (61)	8.23[bc] (67)	9.18[bcd] (83)	10.04[bc] (100)
Clodinafop + Metribuzin	0.216	56	6.75[b] (44)	7.52[b] (56)	8.55[bc] (72)	9.75[b] (94)
2,4-D amine	0.500	50	4.17[a] (16.6)	4.17[a] (17)	4.80[a] (22)	5.83[a] (33)
Bispyribac sodium	0.025	61	8.15[bc] (67)	8.86[bcd] (78)	9.5[bcd] (89)	10.34[bc] (106)
Metribuzin	0.120	44	7.52[bc] (56)	8.23[bc] (67)	8.21[b] (67)	9.75[b] (94)
Metsulfuron	0.005	56	7.88[bc] (61)	9.15[cd] (83)	10.04[d] (100)	11.09[c] (122)
Carfentrazone-ethyl	0.020	67	7.88[bc] (61)	7.52[b] (56)	8.21[b] (67)	9.75[b] (94)
Metsulfuron + Carfentrazone-ethyl	0.025	61	8.86[c] (78)	9.15[cd] (83)	10.04[d] (100)	10.04[bc] (100)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	50	7.88[bc] (61)	8.55[bcd] (72)	10.04[d] (100)	10.58[bc] (111)
Ethoxysulfuron	0.018	67	1.00[a] (0)	1.00[a] (0)	4.17[a] (17)	6.32[a] (39)
Halosulfuron	0.050	56	1.00[a] (0)	1.00[a] (0)	1.00[a] (0)	4.80[a] (22)
Atrazine	1.000	50	6.75[b] (44)	7.52[b] (56)	8.55[bc] (72)	9.49[b] (89)
Two hand weedings (15 days interval)	-	61	1.00[a] (0)	1.00[a] (0)	4.17[a] (17)	5.39[a] (28)
Un-weeded (control)	-	56	8.21[bc] (67)	9.77[d] (94)	10.04[d] (100)	11.09[c] (122)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.1.10: Fresh weight of weeds before the spray of post-emergence herbicides

The fresh weight of grasses, broadleaf and sedges before the spray of herbicides ranged between 33.33 to 43.88 g m^{-2} at Location I, whereas this range was 16.67 to 33.55g m^{-2} and 11.11 to 16.67 g m^{-2} at Location II and Location III, respectively. The range of broadleaf weed was 38.89 to 57.77 g m^{-2}, 173.87 to 270.53 g m^{-2} and 72.22 to 100.55 g m^{-2} at Location I, Location II and Location III, respectively. In sedges, the range was 3.33 to 5.56 g m^{-2} at Location I (Table 4.1.16.). However, sedge weeds did not appear at other locations. The fresh weight difference of different categories of weeds was non-significant as the data was recorded before the herbicide spray.

Table 4.1.16: Fresh weight of weeds before the spray of post-emergence herbicides at different locations in lawn during winter season

Treatments	Fresh weight (g m^{-2})						
	Grasses			Broadleaf			Sedges
	Location I	Location II	Location III	Location I	Location II	Location III	Location I
Isoproturon	43.88	30.55	12.22	40.55	179.43	72.22	3.89
Mesosulfuron + Iodosulfuron	36.11	16.67	12.22	43.33	211.65	83.33	4.44
Clodinafop + Metribuzin	35.55	19.43	12.22	46.66	268.31	91.66	5.00
2,4-D amine	39.44	19.43	12.22	51.66	173.87	82.77	5.56
Bispyribac sodium	36.11	22.22	12.22	42.22	243.86	87.21	4.44
Metribuzin	37.77	27.78	16.67	48.33	191.65	91.66	4.44
Metsulfuron	38.89	33.33	13.89	46.11	270.53	93.88	5.55
Carfentrazone-ethyl	36.11	16.67	15.00	38.89	251.09	83.33	5.00
Metsulfuron + Carfentrazone -ethyl	36.11	27.78	15.00	50.55	232.75	79.99	5.00
Metsulfuron-methyl + Chlorimuron-ethyl	33.33	25.00	13.33	49.44	247.20	83.33	4.44
Ethoxysulfuron	33.33	25.00	13.33	43.33	247.20	82.77	3.33
Halosulfuron	38.89	30.55	12.22	57.77	227.20	91.10	5.00
Atrazine	38.33	25.04	11.11	48.33	234.98	96.66	3.89
Two hand weedings (15 days interval)	36.11	16.67	13.89	50.00	221.64	99.99	5.00
Un-weeded (control)	43.33	30.55	14.44	48.88	232.75	100.55	5.56

4.1.11: Dry weight of weeds before the spray of post-emergence herbicides

The dry weight of grasses, broadleaf and sedges before the application of herbicide treatments at different locations ranged between 5.33 to 7.02g m^{-2} at Location I, whereas this range was 2.67 to 5.33g and 1.78 to 2.67g m^{-2} at Location II and Location III, respectively (Table 4.1.17.). The range of broadleaf was 6.49 to 8.62g, 27.82 to 43.28g and 11.55 to 16.09g m^{-2} at Location I, Location II and location III, respectively. In sedges, range was 0.62 to 0.89 g m^{-2} at location I. However, sedges did not appear at other two locations. The difference in the dry weight of weeds was non-significant as the data was recorded before the spray of herbicides.

Table 4.1.17: Dry weight of weeds before the spray of post-emergence herbicides at different locations in lawn

Treatments	Dry weight (g m^{-2}) before spray						
	Grasses			Broadleaf			Sedges
	Location I	Location II	Location III	Location I	Location II	Location III	Location I
Isoproturon	7.02	4.89	1.94	6.49	28.71	11.55	0.62
Mesosulfuron + Iodosulfuron	5.78	2.67	1.96	6.93	33.86	13.33	0.71
Clodinafop + Metribuzin	5.69	3.11	1.96	6.67	42.93	14.67	0.80
2,4-D amine	6.31	3.11	1.96	8.27	27.82	13.24	0.89
Bispyribac sodium	5.78	3.56	1.98	6.75	39.02	13.95	0.71
Metribuzin	6.04	4.44	2.67	7.73	30.66	14.67	0.71
Metsulfuron	6.22	5.33	2.22	7.38	43.28	15.02	0.89
Carfentrazone-ethyl	5.78	2.67	2.40	6.22	40.17	13.33	0.80
Metsulfuron + Carfentrazone-ethyl	5.78	4.44	2.40	8.09	37.24	12.80	0.80
Metsulfuron-methyl + Chlorimuron-ethyl	5.33	4.00	2.13	7.91	39.55	13.33	0.71
Ethoxysulfuron	5.33	4.00	2.13	6.93	39.55	13.24	0.71
Halosulfuron	6.22	4.89	1.96	7.43	36.35	14.58	0.80
Atrazine	6.13	4.01	1.78	7.73	37.60	15.47	0.62
Two hand weedings (15 days interval)	5.78	2.67	2.22	8.00	35.46	16.00	0.80
Un-weeded (control)	6.93	4.89	2.31	7.82	37.24	16.09	0.89

4.1.12: Dry weight of grass weeds after spray of herbicides during winter season

The dry weight of grasses when recorded after 15 days of different herbicides application revealed that all the weed control treatments significantly affected the weed dry weight as compared with weedy check (Table 4.1.18.). However, isoproturon @ 0.937 kg ha^{-1}, mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1}, clodinafop + metribuzin @ 0.216 kg ha^{-1}, bispyribac sodium @ 0.025 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, ethoxysulfuron @ 0.018 kg ha^{-1} and two hand weedings recorded the lowest dry weight and significantly lower as compared with other herbicides.

Table 4.1.18: Effect of post-emergence herbicides on dry weight of grass weeds at different locations 15 DAS in lawn during winter season

Treatments	Dose (kg ha^{-1})	Grasses dry weight (g m^{-2}) at 15 DAS		
		Location I	Location II	Location III
Isoproturon	0.937	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Mesosulfuron + Iodosulfuron	0.014	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Clodinafop + Metribuzin	0.216	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
2,4-D amine	0.500	2.96^{b} (7.77)	2.68^{cd} (6.2)	2.17^{cd} (3.73)
Bispyribac sodium	0.025	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metribuzin	0.120	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron	0.005	3.05^{b} (8.39)	2.53^{bc} (5.4)	2.10^{bc} (3.42)
Carfentrazone-ethyl	0.020	2.95^{b} (7.77)	2.20^{b} (3.8)	2.28^{cd} (4.20)
Metsulfuron + Carfentrazone-ethyl	0.025	2.85^{b} (7.15)	2.53^{bc} (5.44)	2.21^{cd} (3.89)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	2.74^{b} (6.53)	2.36^{bc} (4.6)	2.17^{cd} (3.73)
Ethoxysulfuron	0.018	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Halosulfuron	0.050	2.68^{b} (6.22)	2.20^{b} (3.8)	1.94^{b} (2.80)
Atrazine	1.000	2.82^{b} (6.99)	2.20^{b} (3.8)	1.94^{b} (2.80)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	3.55^{c} (11.66)	2.95^{d} (7.7)	2.34^{d} (4.51)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.1.13: Dry weight of broadleaf weeds after spray of herbicides during winter season

The dry weight of broadleaf weeds when recorded after 15 and 30 days of different herbicides application at different locations as presented in Table 4.1.19. revealed that hand weeding treatment significantly lowered the dry weight of weeds at 15 DAS followed by isoproturon @ 0.937 kg ha^{-1}, clodinafop + metribuzin @ 0.216 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1}, carfentrazone-ethyl @ 0.020 kg ha^{-1}, metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1}, metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1} and atrazine @ 1 kg ha^{-1}. At 30 DAS, metsulfuron + carfentrazone-ethyl @ 0.025 kg ha $^{-1}$ and two hand weedings provided complete control of broadleaf weeds and recorded the lowest dry weight which was significantly lower as compared with other herbicide treatments and weedy check. Dry weight of broadleaf weeds when recorded after 45 and 60 DAS (Table 4.1.20.) showed that metsulfuron + carfentrazone-ethyl @ 0.025 kg ha $^{-1}$ provided complete control of broadleaf weeds upto 60 DAS and recorded the lowest dry weight (0 g m^{-2}) which was significantly lower as compared with other herbicide treatments and weedy check. Re-sprouting of broadleaf weeds was observed at 60 DAS in all the treatments except metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1}.

Table 4.1.19: Effect of post-emergence herbicides on periodic dry weight of broadleaf weeds at different locations 15 and 30 DAS

Treatments	Dose (kg ha^{-1})	Dry weight of broadleaf weeds (g m^{-2})					
		15 DAS			30 DAS		
		Location I	Location II	Location III	Location I	Location II	Location III
Isoproturon	0.937	2.05^{abc} (3.26)	4.33^{bcde} (17.75)	2.86^{c} (7.18)	2.09^{abc} (3.40)	4.33^{cd} (17.75)	2.86^{de} (7.18)
Mesosulfuron + Iodosulfuron	0.014	2.85^{def} (7.15)	6.10^{fg} (36.22)	3.75^{d} (13.03)	3.22^{e} (9.30)	6.20^{f} (37.49)	4.28^{hi} (17.33)
Clodinafop + Metribuzin	0.216	1.90^{ab} (2.64)	3.26^{abc} (9.63)	3.12^{c} (8.87)	2.09^{abc} (3.40)	3.26^{b} (9.63)	2.54^{cd} (5.48)
2,4-D amine	0.500	3.18^{ef} (9.17)	4.70^{bcdef} (21.15)	3.74^{d} (13.07)	3.18^{e} (9.17)	4.71^{d} (21.15)	3.75^{g} (13.07)
Bispyribac sodium	0.025	3.28^{f} (9.80)	5.55^{efg} (29.86)	3.80^{de} (13.41)	3.28^{e} (9.80)	5.49^{e} (29.09)	3.80^{g} (13.41)
Metribuzin	0.120	2.10^{bc} (3.42)	3.57^{abcd} (11.77)	3.01^{c} (8.09)	2.35^{bcd} (4.53)	3.57^{bc} (11.78)	2.89^{de} (7.33)
Metsulfuron	0.005	2.24^{bcd} (4.04)	2.96^{ab} (7.78)	2.57^{bc} (5.60)	2.13^{abc} (3.58)	2.58^{ab} (5.62)	2.19^{bc} (3.78)
Carfentrazone-ethyl	0.020	1.95^{abc} (2.80)	3.26^{abc} (9.63)	2.96^{c} (7.78)	2.38^{bcd} (4.72)	3.89^{bc} (14.17)	2.92^{de} (7.39)
Metsulfuron + Carfentrazone-ethyl	0.025	2.02^{ab} (3.11)	2.20^{ab} (3.89)	1.78^{ab} (2.18)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	2.53^{bcd} (5.44)	4.73^{cdef} (21.46)	2.94^{c} (7.62)	2.85^{cde} (7.17)	3.69^{bc} (12.65)	2.92^{de} (7.55)
Ethoxysulfuron	0.018	2.65^{cde} (6.06)	5.47^{defg} (28.93)	3.95^{de} (14.62)	2.98^{de} (7.93)	6.40^{f} (40.00)	3.57^{fg} (11.71)
Halosulfuron	0.050	3.32^{f} (10.1)	6.15^{fg} (36.83)	4.20^{e} (16.62)	3.34^{e} (10.20)	6.15^{f} (36.83)	4.20^{h} (16.62)
Atrazine	1.000	2.37^{bcd} (4.67)	4.27^{abcde} (17.26)	2.77^{c} (6.69)	2.41^{bcd} (4.77)	4.96^{de} (23.61)	2.35^{bcd} (4.53)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	4.60^{g} (20.20)	8.07^{h} (64.08)	4.63^{f} (20.40)	4.77^{f} (21.77)	8.07^{g} (64.08)	4.63^{i} (20.40)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

Table 4.1.20: Effect of post-emergence herbicides on periodic dry weight of broadleaf weeds at different locations 45 and 60 DAS

Treatments	Dose (kg ha^{-1})	Dry weight of broadleaf weeds (g m^{-2})					
		45 DAS			60 DAS		
		Location I	Location II	Location III	Location I	Location II	Location III
Isoproturon	0.937	2.55^{bcd} (5.55)	4.98^{cd} (23.78)	3.45^{def} (10.89)	3.33^{cd} (10.22)	5.45^{c} (28.71)	4.28^{f} (17.33)
Mesosulfuron + Iodosulfuron	0.014	3.00^{cde} (8.00)	6.20^{ef} (37.49)	4.28^{g} (17.33)	3.38^{cd} (10.44)	6.49^{d} (41.11)	4.53^{fg} (19.55)
Clodinafop + Metribuzin	0.216	2.09^{ab} (3.40)	3.87^{b} (14.00)	3.00^{cd} (8.00)	2.55^{b} (5.55)	4.53^{bc} (19.55)	3.51^{d} (11.33)
2,4-D amine	0.500	3.18^{de} (9.17)	5.15^{d} (24.55)	3.96^{fg} (14.67)	3.78^{de} (13.33)	5.11^{bc} (25.11)	4.23^{f} (16.89)
Bispyribac sodium	0.025	3.47^{ef} (11.05)	6.01^{ef} (35.11)	4.31^{gh} (17.55)	5.17^{f} (25.77)	6.30^{d} (38.66)	4.90^{gh} (23.02)
Metribuzin	0.120	2.35^{bc} (4.53)	3.81^{b} (13.55)	3.42^{de} (10.67)	2.68^{b} (6.22)	4.33^{b} (17.75)	3.64^{de} (12.25)
Metsulfuron	0.005	2.38^{bc} (4.67)	3.75^{b} (13.03)	1.79^{ab} (2.22)	2.84^{bc} (7.11)	4.83^{bc} (22.31)	2.33^{b} (4.44)
Carfentrazone-ethyl	0.020	2.55^{bcd} (5.55)	4.20^{bc} (16.67)	3.17^{d} (9.07)	2.68^{b} (6.22)	4.93^{bc} (23.33)	3.17^{cd} (9.07)
Metsulfuron + Carfentrazone-ethyl	0.025	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	3.10^{de} (8.66)	5.69^{de} (31.33)	3.38^{de} (10.44)	3.41^{cd} (10.66)	4.73^{bc} (21.33)	3.67^{de} (12.44)
Ethoxysulfuron	0.018	2.98^{cde} (7.93)	6.40^{fg} (40.00)	3.90^{efg} (14.22)	3.57^{d} (11.77)	7.30^{e} (52.22)	4.15^{ef} (16.22)
Halosulfuron	0.050	3.77^{f} (13.33)	6.94^{g} (47.11)	4.73^{h} (21.33)	4.14^{e} (16.22)	7.19^{e} (50.66)	4.84^{g} (22.44)
Atrazine	1.000	2.37^{bc} (4.66)	4.96^{cd} (23.61)	2.35^{bc} (4.53)	2.84^{bc} (7.11)	4.96^{bc} (23.61)	2.60^{bc} (5.78)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	2.33^{b} (4.44)	2.19^{a} (3.78)	1.97^{ab} (2.89)
Un-weeded (control)	-	5.46^{g} (28.88)	8.24^{h} (66.99)	4.90^{i} (23.09)	5.50^{f} (29.33)	8.42^{f} (69.91)	5.28^{h} (26.89)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.1.14: Dry weight of sedges after spray of different herbicides during winter season

The dry weight of sedges recorded after 15, 30, 45 and 60 days of different herbicides application at Location I are presented in Table 4.1.21 revealed that the lowest dry weight was recorded in ethoxysulfuron @ 0.018 kg ha^{-1}, halosulfuron @ 0.050 kg ha^{-1} and hand weeding treatment which was significantly lower than all other herbicide treatments and unweeded check upto 30 DAS. 2,4-D amine @ 0.5 kg ha^{-1} proved to be at par with these treatments the second-best treatment for the control of this weed. Halosulfuron @ 0.050 kg ha^{-1} provided complete control upto 45 DAS and the sedge weeds showed re-sprouting when observed at 60 DAS whereas re-sprouting was recorded in ethoxysulfuron @ 0.018 kg ha^{-1} and hand weeding treatments when observed at 45 DAS. The weeds belonging to sedges did not appear at other locations.

Table 4.1.21: Effect of post-emergence herbicides on periodic dry weight of sedges

Treatments	Dose (kg ha^{-1})	Dry weight of sedges (g m^{-2})			
		15 DAS	30 DAS	45DAS	60 DAS
Isoproturon	0.937	1.59^{bc} (1.56)	1.95^{def} (2.83)	2.51^{cd} (5.33)	2.89^{cd} (7.33)
Mesosulfuron + Iodosulfuron	0.014	1.59^{bc} (1.56)	1.90^{cde} (2.64)	2.47^{cd} (5.11)	2.77^{cd} (6.67)
Clodinafop + Metribuzin	0.216	1.49^{bc} (1.24)	1.75^{bc} (2.08)	2.51^{cd} (5.33)	2.81^{cd} (6.89)
2,4-D amine	0.500	1.10^{a} (0.21)	1.10^{a} (0.21)	1.14^{a} (0.30)	2.18^{ab} (3.77)
Bispyribac sodium	0.025	1.69^{c} (1.87)	1.95^{def} (2.83)	2.46^{cd} (5.11)	3.07^{de} (8.41)
Metribuzin	0.120	1.69^{c} (1.87)	1.95^{def} (2.83)	2.33^{c} (4.44)	2.69^{c} (6.22)
Metsulfuron	0.005	1.69^{c} (1.87)	2.09^{fg} (3.40)	2.47^{cd} (5.11)	3.07^{de} (8.44)
Carfentrazone-ethyl	0.020	1.44^{b} (1.09)	1.75^{bc} (2.08)	2.33^{c} (4.44)	3.04^{d} (8.22)
Metsulfuron + Carfentrazone-ethyl	0.025	1.54^{bc} (1.40)	1.90^{cde} (2.64)	2.51^{cd} (5.33)	2.89^{cd} (7.33)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	1.59^{bc} (1.56)	2.10^{ef} (3.02)	2.37^{cd} (4.66)	2.89^{cd} (7.33)
Ethoxysulfuron	0.018	1^{a} (0)	1^{a} (0)	1.37^{a} (0.89)	2.18^{ab} (3.77)
Halosulfuron	0.050	1^{a} (0)	1^{a} (0)	1^{a} (0)	1.79^{a} (2.22)
Atrazine	1.000	1.49^{bc} (1.24)	1.80^{cd} (2.27)	2.28^{c} (4.22)	2.56^{bc} (5.55)
Two hand weedings (15 days interval)	-	1^{a} (0)	1^{a} (0)	1.37^{a} (0.89)	1.79^{a} (2.22)
Un-weeded (control)	-	1.94^{d} (2.80)	2.18^{g} (3.78)	2.60^{d} (5.77)	3.35^{e} (10.22)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.1.15: Total dry weight of weeds before the spray post-emergence herbicides

The total dry weight of weeds before the application of herbicide treatments at different locations are presented in Table 4.3.6. The total dry weight ranged between 12.80 to 15.64 g m^{-2} at Location I, whereas this range was 29.60 to 48.62 g and 13.49 to 18.40 g m^{-2} at Location II and Location III, respectively. The total dry weight difference of weeds was non-significant as the dry weight was recorded before the application of herbicides spray.

Table 4.1.22: Total dry weight of weeds before the spray post-emergence herbicides at different locations in lawn during winter season

Treatments	Total dry weight (g m^{-2}) before spray		
	Location I	Location II	Location III
Isoproturon	14.13	33.60	13.49
Mesosulfuron + Iodosulfuron	13.42	36.53	15.29
Clodinafop + Metribuzin	13.15	44.71	16.63
2,4-D amine	15.47	29.60	15.20
Bispyribac sodium	13.24	42.57	15.94
Metribuzin	14.49	35.11	17.33
Metsulfuron	14.49	48.62	17.24
Carfentrazone-ethyl	12.80	42.84	15.73
Metsulfuron + Carfentrazone-ethyl	14.67	41.68	15.20
Metsulfuron-methyl + Chlorimuron-ethyl	13.95	43.55	15.47
Ethoxysulfuron	12.98	41.33	15.38
Halosulfuron	14.45	41.24	16.53
Atrazine	14.49	39.37	17.24
Two hand weedings (15 days interval)	14.58	38.13	18.22
Un-weeded (control)	15.64	43.46	18.40

4.1.16: Total dry weight of weeds after spray post-emergence herbicides in winter season

The total dry weight of weeds when recorded after 15 and 30 days of different herbicides application at different locations as presented in Table 4.1.23 revealed that hand weeding treatment significantly lowered the dry weight of weeds at 15 DAS followed by clodinafop + metribuzin @ 0.216 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1}. At 30 DAS two hand weeding treatment provided complete control of weeds and metsulfuron + carfentrazone-ethyl @ 0.025 kg ha $^{-1}$ recorded the lowest dry weight followed by clodinafop + metribuzin @ 0.216 kg ha^{-1} which was significantly lower as compared with other herbicide treatments and weedy check. When recorded after 45 and 60 days of different herbicides application at different locations as presented in Table 4.3.8 revealed that metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} hand weeding treatment significantly lowered the dry weight of weeds at 45 DAS as compared with all other treatments. At 60 DAS, re-sprouting of weeds was observed in all the treatments however, the dry weight was significantly the lowest in metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and hand weeding treatment and better than all the herbicide treatments.

Table 4.1.23: Effect of post-emergence herbicides on periodic total dry weight of weeds at different locations 15 and 30 DAS in lawn

Treatments	Dose (kg ha^{-1})	Total dry weight of weeds (g m^{-2})					
		15 DAS			30 DAS		
		Location I	Location II	Location III	Location I	Location II	Location III
Isoproturon	0.937	2.41^{bc} (4.82)	4.33^{cd} (17.75)	2.86^{b} (7.18)	2.69^{cd} (6.23)	4.33^{de} (17.75)	2.86^{c} (7.18)
Mesosulfuron + Iodosulfuron	0.014	3.12^{cd} (8.71)	6.10^{gh} (36.22)	3.75^{ef} (13.03)	3.60^{f} (11.94)	6.20^{g} (37.49)	4.28^{ef} (17.33)
Clodinafop + Metribuzin	0.216	2.21^{ab} (3.89)	3.26^{b} (9.63)	3.14^{bcd} (8.87)	2.55^{bc} (5.48)	3.26^{bc} (9.63)	2.55^{bc} (5.48)
2,4-D amine	0.500	4.26^{g} (17.16)	5.33^{ef} (27.38)	4.22^{gh} (16.8)	3.22^{def} (9.39)	4.71^{e} (21.15)	3.75^{d} (13.07)
Bispyribac sodium	0.025	3.56^{de} (11.67)	5.56^{fg} (29.86)	3.80^{fg} (13.41)	3.69^{f} (12.63)	5.49^{f} (29.09)	3.80^{d} (13.41)
Metribuzin	0.120	2.51^{bc} (5.29)	3.57^{bc} (11.78)	3.01^{bc} (8.09)	2.89^{cde} (7.37)	3.57^{bcd} (11.78)	2.89^{c} (7.33)
Metsulfuron	0.005	3.91^{efg} (14.31)	3.77^{bc} (13.22)	3.17^{bcd} (9.02)	2.83^{cde} (6.99)	2.57^{ab} (5.62)	2.19^{b} (3.78)
Carfentrazone-ethyl	0.020	3.56^{de} (11.67)	3.81^{bc} (13.52)	3.6^{def} (11.98)	2.79^{cde} (6.8)	3.89^{cd} (14.17)	2.90^{c} (7.39)
Metsulfuron + Carfentrazone-ethyl	0.025	3.56^{de} (11.67)	3.21^{b} (9.33)	2.66^{b} (6.07)	1.91^{ab} (2.64)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	3.81^{efg} (13.53)	5.21^{ef} (26.13)	3.51^{cdef} (11.35)	3.35^{ef} (10.2)	3.69^{cd} (12.65)	2.92c (7.55)
Ethoxysulfuron	0.018	2.66^{bc} (6.07)	5.47^{f} (28.93)	3.95^{fg} (14.62)	2.99^{cde} (7.93)	6.40^{g} (40.00)	3.57^{d} (11.71)
Halosulfuron	0.050	4.16^{fg} (16.32)	6.46^{h} (40.72)	4.52^{h} (19.42)	3.35^{ef} (10.2)	6.15^{g} (36.83)	4.20^{e} (16.62)
Atrazine	1.000	3.73^{ef} (12.91)	4.71^{de} (21.15)	3.24^{bcde} (9.49)	2.84^{cde} (7.04)	4.96^{ef} (23.61)	2.35^{bc} (4.53)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	5.97^{h} (34.67)	8.54^{i} (71.86)	5.09^{i} (24.91)	5.15^{g} (25.55)	8.07^{h} (64.08)	4.63^{f} (20.4)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

Table 4.1.24: Effect of post-emergence herbicides on periodic total dry weight of weeds at different locations 45 and 60 DAS in lawn

Treatments	Dose (kg ha^{-1})	Total dry weight of weeds (g m^{-2})					
		45 DAS			60 DAS		
		Location I	Location II	Location III	Location I	Location II	Location III
Isoproturon	0.937	3.45^{cde} (10.89)	4.98^{cd} (23.78)	3.45^{def} (10.89)	4.31^{de} (17.55)	5.45^{c} (28.71)	4.28^{f} (17.33)
Mesosulfuron + Iodosulfuron	0.014	3.76^{def} (13.11)	6.20^{ef} (37.49)	4.28^{h} (17.33)	4.26^{de} (17.11)	6.49^{d} (41.11)	4.53^{fg} (19.55)
Clodinafop + Metribuzin	0.216	3.12^{bc} (8.73)	3.87^{b} (14)	3.00^{cd} (8.00)	3.67^{bc} (12.44)	4.53^{bc} (19.55)	3.51^{d} (11.33)
2,4-D amine	0.500	3.24^{cd} (9.48)	5.15^{d} (25.55)	3.96^{gh} (14.67)	4.26^{de} (17.11)	5.11^{bc} (25.11)	4.23^{f} (16.89)
Bispyribac sodium	0.025	4.14^{f} (16.16)	6.01^{ef} (35.11)	4.31^{hi} (17.55)	5.93^{e} (34.19)	6.30^{d} (38.66)	4.90^{gh} (23.02)
Metribuzin	0.120	3.16^{bc} (8.98)	3.81^{b} (13.55)	3.42^{de} (10.67)	3.67^{bc} (12.44)	4.33^{b} (17.75)	3.64^{de} (12.25)
Metsulfuron	0.005	3.28^{cde} (9.78)	3.75^{b} (13.03)	1.79^{ab} (2.22)	4.07^{cde} (15.55)	4.83^{bc} (22.31)	2.33^{b} (4.44)
Carfentrazone-ethyl	0.020	3.32^{cde} (10.00)	4.20^{bc} (16.67)	3.17^{d} (9.07)	3.93^{bcd} (14.44)	4.93^{bc} (23.33)	3.17^{cd} (9.07)
Metsulfuron + Carfentrazone-ethyl	0.025	2.52^{b} (5.33)	1.00^{a} (0)	1.00^{a} (0)	3.57^{b} (11.77)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	3.79^{ef} (13.33)	5.69^{de} (31.33)	3.38^{de} (10.44)	4.36^{d} (18.00)	4.73^{bc} (21.33)	3.67^{de} (12.44)
Ethoxysulfuron	0.018	3.13^{bc} (8.82)	6.40^{fg} (40)	3.90^{fgh} (14.22)	4.07^{cde} (15.55)	7.30^{e} (52.22)	4.15^{ef} (16.22)
Halosulfuron	0.050	3.79^{ef} (13.33)	6.94^{g} (47.11)	4.73^{i} (21.33)	4.41^{d} (18.44)	7.19^{e} (50.66)	4.84^{g} (22.44)
Atrazine	1.000	3.14^{bc} (8.89)	4.96^{cd} (23.61)	2.35^{bc} (4.53)	3.70^{bc} (12.67)	4.96^{bc} (23.61)	2.60^{bc} (5.78)
Two hand weedings (15 days interval)	-	1.37^{a} (0.89)	1.00^{a} (0)	1.00^{a} (0)	2.77^{a} (6.67)	2.19^{a} (3.78)	1.97^{ab} (2.89)
Un-weeded (control)	-	5.97^{g} (34.66)	8.24^{h} (66.99)	4.90^{i} (23.09)	6.37^{f} (39.55)	8.42^{f} (69.91)	5.28^{h} (26.89)

*Values in the parentheses are original means. Data was subjected to square root transformation √(x+1)

Table 4.1.25: Weed control efficiency of different post-emergence herbicides at 15 and 30 DAS in lawn during winter season

Treatments	**Dose ($kg\ ha^{-1}$)**	**Weed control efficiency (%)**							
		15 DAS				**30 DAS**			
		Location I	Location II	Location III	Mean	Location I	Location II	Location III	Mean
Isoproturon	0.937	86.1	75.3	86.1	75.3	86.1	75.3	86.1	75.3
Mesosulfuron + Iodosulfuron	0.014	74.9	49.6	74.9	49.6	74.9	49.6	74.9	49.6
Clodinafop + Metribuzin	0.216	88.8	86.6	88.8	86.6	88.8	86.6	88.8	86.6
2,4-D amine	0.500	50.5	61.9	50.5	61.9	50.5	61.9	50.5	61.9
Bispyribac sodium	0.025	66.3	58.4	66.3	58.4	66.3	58.4	66.3	58.4
Metribuzin	0.120	84.7	83.6	84.7	83.6	84.7	83.6	84.7	83.6
Metsulfuron	0.005	58.7	81.6	58.7	81.6	58.7	81.6	58.7	81.6
Carfentrazone-ethyl	0.020	66.3	81.2	66.3	81.2	66.3	81.2	66.3	81.2
Metsulfuron + Carfentrazone-ethyl	0.025	66.3	87.0	66.3	87.0	66.3	87.0	66.3	87.0
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	61.0	63.6	61.0	63.6	61.0	63.6	61.0	63.6
Ethoxysulfuron	0.018	82.5	59.7	82.5	59.7	82.5	59.7	82.5	59.7
Halosulfuron	0.050	52.9	43.3	52.9	43.3	52.9	43.3	52.9	43.3
Atrazine	1.000	62.8	70.6	62.8	70.6	62.8	70.6	62.8	70.6
Two hand weedings (15 days interval)	-	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Un-weeded (control)	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4.1.26: Weed control efficiency of different post-emergence herbicides at 45 and 60 DAS in lawn during winter season

Treatments	Dose (kg ha^{-1})	Weed control efficiency (%)							
		45 DAS				60 DAS			
		Location I	Location II	Location III	Mean	Location I	Location II	Location III	Mean
Isoproturon	0.937	68.6	66.0	59.5	64.7	55.6	59.0	35.6	50.0
Mesosulfuron + Iodosulfuron	0.014	62.2	46.4	35.6	48.1	56.7	41.3	27.3	41.8
Clodinafop + Metribuzin	0.216	74.8	80.0	70.2	75.0	68.5	72.1	57.9	66.2
2,4-D amine	0.500	72.6	63.5	45.5	60.5	56.7	64.1	37.2	52.7
Bispyribac sodium	0.025	53.4	49.8	34.7	46.0	13.6	44.8	14.4	24.2
Metribuzin	0.120	74.1	80.6	60.3	71.7	68.5	74.6	54.4	65.9
Metsulfuron	0.005	71.8	81.4	91.7	81.6	60.7	68.1	83.5	70.8
Carfentrazone-ethyl	0.020	71.1	76.2	66.3	71.2	63.5	66.7	66.3	65.5
Metsulfuron + Carfentrazone-ethyl	0.025	84.6	100	100	94.9	70.2	100	100	90.0
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	61.5	55.2	61.2	59.3	54.5	69.5	53.7	59.2
Ethoxysulfuron	0.018	74.6	42.9	47.1	54.8	60.7	25.4	39.7	41.9
Halosulfuron	0.050	61.5	32.7	20.7	38.3	53.4	27.6	16.5	32.5
Atrazine	1.000	74.4	66.3	83.1	74.6	68.0	66.3	78.5	70.9
Two hand weedings (15 days interval)	-	97.4	100.0	100.0	99.1	83.1	94.6	89.3	89.0
Un-weeded (control)	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4.1.17: Weed control efficiency of different herbicides in lawn during winter season

Weed control efficiency was calculated at 15, 30, 45 and 60 DAS during winter season and are presented in Table 4.1.25 and Table 4.1.26. Among the herbicide treatments at 15 DAS, hand weeding treatment resulted in obtaining the highest (100%) mean weed control efficiency followed by clodinafop + metribuzin @ 0.216 kg ha^{-1} and metribuzin @ 0.120 kg ha^{-1} as 79.9 and 78.6 per cent, respectively at the different locations. When observed at 30 DAS, the highest (100%) WCE was calculated in hand weeding treatment, followed by 96.6 per cent in metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1}. The weed control efficiency at 45 DAS in hand weeding treatment was 99.1 per cent and that in metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} was 94.9 per cent. At 60 DAS the efficiency of these treatements were slightly lower as 90 and 89 per cent recorded WCE and in metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and hand weeding treatment.

Table 4.1.27: Sward height of turfgrass before mowing 60 DAS at different locations in lawn during winter season

Treatments	Dose (kg ha^{-1})	Sward height (cm)		
		Location I	Location II	Location III
Isoproturon	0.937	7.5^{abcd}	7.1^{bcde}	8.7^{abc}
Mesosulfuron + Iodosulfuron	0.014	6.8^{cd}	6.3^{de}	8.1^{c}
Clodinafop + Metribuzin	0.216	7.3^{bcd}	6.7^{cde}	8.4^{bc}
2,4-D amine	0.500	6.7^{d}	6.1^{e}	7.8^{c}
Bispyribac sodium	0.025	5.5^{e}	5.1^{f}	6.7^{d}
Metribuzin	0.120	7.3^{bcd}	6.8^{cde}	8.5^{abc}
Metsulfuron	0.005	7.6^{abcd}	7.1^{abcd}	8.8^{abc}
Carfentrazone-ethyl	0.020	7.6^{abcd}	7.1^{abcd}	8.8^{abc}
Metsulfuron + Carfentrazone-ethyl	0.025	8.2^{ab}	7.7^{ab}	9.4^{ab}
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	7.5^{abcd}	7.1^{bcde}	8.7^{abc}
Ethoxysulfuron	0.018	7.5^{abcd}	7.1^{abcd}	8.7^{abc}
Halosulfuron	0.050	7.4^{abcd}	6.9^{bcde}	8.6^{abc}
Atrazine	1.000	7.7^{abc}	7.2^{abc}	8.9^{abc}
Two hand weedings (15 days interval)	-	8.4^{a}	7.9^{a}	9.6^{a}
Un-weeded (control)	-	4.9^{e}	4.4^{f}	6.1^{d}

4.1.18: Sward height of turfgrass before mowing 60 DAS

Sward height of turfgrass was measured by scale at 60 DAS before mowing. The values as presented in Table 4.1.27 revealed that all the weed control treatments showed significantly more sward height as compared with weedy check except bispyribac sodium @ 0.025 kg ha^{-1} at all the locations. The average sward height was the highest in hand weeding treatment followed by metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1}, atrazine @ 1 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1}, carfentrazone-ethyl @ 0.020 kg ha^{-1} and it was recorded the lowest in weedy check. As the total dry weight of weeds was less in the different weed control treatments, the sward height was more (Table 4.1.24.) The highest sward height was exhibited by the treatments having lower weed density of different weeds (Table 4.1.1. – 4.1.15.) and more weed control efficiency (Table 4.1.26.).

Table 4.1.28: Turfgrass colour before mowing 60 DAS at different locations in lawn during winter season

Treatments	Dose (kg ha^{-1})	Turfgrass colour (1-9 scale)		
		Location I	Location II	Location III
Isoproturon	0.937	8	8	8
Mesosulfuron + Iodosulfuron	0.014	8	8	8
Clodinafop + Metribuzin	0.216	8	8	8
2,4-D amine	0.500	8	8	8
Bispyribac sodium	0.025	8	8	8
Metribuzin	0.120	8	8	8
Metsulfuron	0.005	8	8	8
Carfentrazone-ethyl	0.020	8	8	8
Metsulfuron + Carfentrazone-ethyl	0.025	8	8	8
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	8	8	8
Ethoxysulfuron	0.018	8	8	8
Halosulfuron	0.050	8	8	8
Atrazine	1.000	8	8	8
Two hand weedings (15 days interval)	-	8	8	8
Un-weeded (control)	-	8	8	8

4.1.19: Turfgrass colour before mowing 60 DAS

Turfgrass colour was recorded as 1-9 scale (Voss, 2002) at 60 DAS before mowing and the ratings are presented in Table 4.1.28. The difference in the turfgrass colour was non-significant as the colour was recorded before mowing at 60 DAS during winter season.

4.1.20: Fresh weight of turfgrass clippings after mowing 60 DAS

The fresh weight of turfgrass clippings was calculated at 60 DAS after mowing are presented in Table 4.1.29. Among the herbicide treatments, hand weeding treatment resulted in obtaining the maximum fresh weight followed by metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and isoproturon @ 0.937 kg ha^{-1}. Minimum fresh weight of turfgrass was recorded in un-weeded control. The fresh weight of clippings varied as per the weed density (Table 4.1.1.-4.1.15.) and total fresh and dry weight of weeds (Table 4.1.16 and Table 4.1.22.) The maximum fresh weight of clippings was exhibited by treatments having less weeds and more weed control efficiency.

Table 4.1.29: Fresh weight of turfgrass clippings after mowing 60 DAS at different locations in lawn during winter season

Treatments	Dose (kg ha^{-1})	Fresh weight of clippings (g m^{-2})		
		Location I	Location II	Location III
Isoproturon	0.937	108.0[a]	90.5[ab]	127.5[ab]
Mesosulfuron + Iodosulfuron	0.014	88.5[ab]	71.0[abc]	108.0[c]
Clodinafop + Metribuzin	0.216	91.3[ab]	73.8[ab]	110.8[c]
2,4-D amine	0.500	91.0[ab]	73.5[ab]	110.5[c]
Bispyribac sodium	0.025	85.0[ab]	67.5[bc]	104.5[c]
Metribuzin	0.120	95.5[a]	78.0[ab]	115.0[bc]
Metsulfuron	0.005	97.0[a]	79.5[ab]	116.5[abc]
Carfentrazone-ethyl	0.020	97.5[a]	80.0[ab]	117.0[abc]
Metsulfuron + Carfentrazone-ethyl	0.025	107.6[a]	90.1[ab]	127.1[ab]
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	88.0[ab]	70.5[abc]	107.5[c]
Ethoxysulfuron	0.018	90.3[ab]	72.8[ab]	109.8[c]
Halosulfuron	0.050	90.0[ab]	72.5[ab]	109.5[c]
Atrazine	1.000	95.7[a]	78.2[ab]	115.2[bc]
Two hand weedings (15 days interval)	-	111.0[a]	93.5[a]	13.05[a]
Un-weeded (control)	-	63.0[b]	45.5[c]	82.5[d]

Table 4.1.30: Dry weight of turfgrass clippings after mowing 60 DAS at different locations in lawn during winter season

Treatments	Dose (kg ha^{-1})	Dry weight of clippings (g m^{-2})		
		Location I	Location II	Location III
Isoproturon	0.937	40.61[a]	28.24[ab]	53.30[ab]
Mesosulfuron + Iodosulfuron	0.014	33.28[ab]	22.15[abc]	45.14[c]
Clodinafop + Metribuzin	0.216	34.33[ab]	23.03[ab]	46.31[c]
2,4-D amine	0.500	34.22[ab]	22.93[ab]	46.19[c]
Bispyribac sodium	0.025	31.97[ab]	21.07[bc]	43.69[c]
Metribuzin	0.120	35.91[a]	24.34[ab]	48.07[bc]
Metsulfuron	0.005	36.47[a]	24.80[ab]	48.70[abc]
Carfentrazone-ethyl	0.020	36.66[a]	24.96[ab]	48.91[abc]
Metsulfuron + Carfentrazone-ethyl	0.025	40.46[a]	28.11[ab]	53.13[ab]
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	33.09[ab]	22.00[abc]	44.94[c]
Ethoxysulfuron	0.018	33.97[ab]	22.72[ab]	45.91[c]
Halosulfuron	0.050	33.84[ab]	22.62[ab]	45.77[c]
Atrazine	1.000	35.97[a]	24.39[ab]	48.14[bc]
Two hand weedings (15 days interval)	-	41.74[a]	29.17[a]	54.55[a]
Un-weeded (control)	-	23.69[b]	14.20[c]	34.49[d]

4.1.21: Dry weight of turfgrass clippings after mowing 60 DAS

The dry weight of turfgrass clippings during winter season was recorded at 60 DAS after mowing and presented in Table 4.1.30. Among the herbicide treatments, hand weeding treatment resulted in obtaining the maximum dry weight followed by metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and isoproturon at 0.937 kg ha^{-1}. Minimum dry weight ofturfgrass was recorded in un-weeded control in different locations. The values varied accordingto presence of weed density (Table 4.1.1 to Table 4.1.15.) and total dry weight of weeds (Table4.1.22.) The maximum dry weight of clippings was exhibited by treatments having less densityof weeds and more weed control efficiency (Table 4.1.26.).

The total weed dry weight and dry weight of turfgrass clippings in lawn during winter season was negatively correlated at 60 DAS after mowing. The presence of weeds had affected the dry weight of turfgrass (54 – 66 %) at all the locations (Fig. 3).

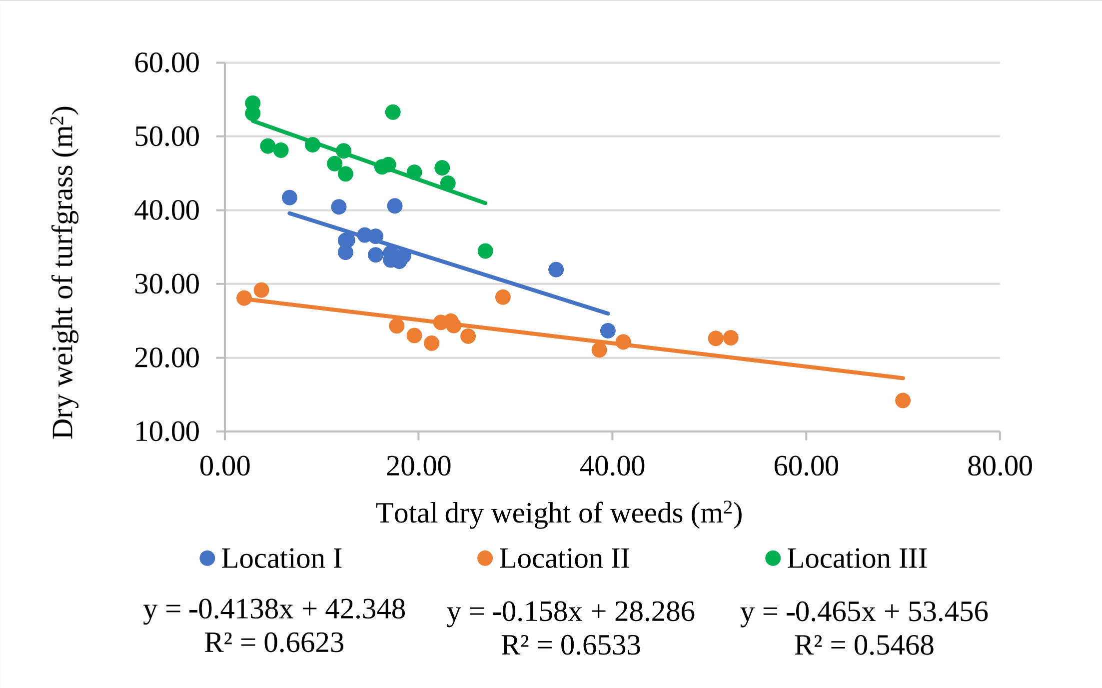

Fig. 3: Correlation of dry weight of weeds and dry weight of turfgrass during winter season.

4.1.22: Effect of different post-emergence herbicides on turfgrass injury

The turfgrass injury ratings recorded weekly using scale 1-9, (where 9 was attributed no injury and 1 as completely necrotic) are presented in Table 4.1.31. The study revealed that grasses, broadleaf weeds and sedges were controlled very effectively with use of herbicide treatments at different locations without showing any toxic symptoms on the turfgrass (*Cynodon dactylon*) except clodinafop + metribuzin @ 0.216 kg ha^{-1}. The symptoms of toxicitywere slight injury and discoloration of topmost leaves and recovered at 35 DAS.

Table 4.1.31: Effect of different post-emergence herbicides on turfgrass injury

Treatments	Dose (kg ha^{-1})	Turfgrass injury (1-9 scale)					
		0 DAS	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS
Isoproturon	0.937	9	9	9	9	9	9
Mesosulfuron + Iodosulfuron	0.014	9	9	9	9	9	9
Clodinafop + Metribuzin	0.216	9	8	8	8	8	9
2,4-D amine	0.500	9	9	9	9	9	9
Bispyribac sodium	0.025	9	9	9	9	9	9
Metribuzin	0.120	9	9	9	9	9	9
Metsulfuron	0.005	9	9	9	9	9	9
Carfentrazone-ethyl	0.020	9	9	9	9	9	9
Metsulfuron + Carfentrazone-ethyl	0.025	9	9	9	9	9	9
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	9	9	9	9	9	9
Ethoxysulfuron	0.018	9	9	9	9	9	9
Halosulfuron	0.050	9	9	9	9	9	9
Atrazine	1.000	9	9	9	9	9	9
Two hand weedings (15 days interval)	-	9	9	9	9	9	9
Un-weeded (control)	-	9	9	9	9	9	9

Table 4.1.32: Phytotoxicity of post-emergence herbicides in lawn during winter season

Treatments	Dose (kg ha^{-1})	Phytotoxicity (0-10 scale)					
		3 DAS	7 DAS	10 DAS	15 DAS	25 DAS	35 DAS
Isoproturon	0.937	0	0	0	0	0	0
Mesosulfuron + Iodosulfuron	0.014	0	0	0	0	0	0
Clodinafop + Metribuzin	0.216	0	1	1	1	1	0
2,4-D amine	0.500	0	0	0	0	0	0
Bispyribac sodium	0.025	0	0	0	0	0	0
Metribuzin	0.120	0	0	0	0	0	0
Metsulfuron	0.005	0	0	0	0	0	0
Carfentrazone-ethyl	0.020	0	0	0	0	0	0
Metsulfuron + Carfentrazone-ethyl	0.025	0	0	0	0	0	0
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	0	0	0	0	0	0
Ethoxysulfuron	0.018	0	0	0	0	0	0
Halosulfuron	0.050	0	0	0	0	0	0
Atrazine	1.000	0	0	0	0	0	0
Two hand weedings (15 days interval)	-	0	0	0	0	0	0
Un-weeded (control)	-	0	0	0	0	0	0

4.1.23: Phytotoxicity of post-emergence herbicides in lawn

The phytotoxicity rating recorded at 3, 7, 10, 15 and 25 days after application of herbicide treatments at different locations are presented in Table 4.1.32. The study revealed that grasses, broadleaf weeds and sedges were controlled very effectively with use of herbicide treatments at different locations without any phytotoxicity effect on the turfgrass (*Cynodon dactylon*) except clodinafop + metribuzin @ 0.216 kg ha^{-1}. The symptoms of toxicity were slight injury and discoloration of topmost leaves and recovered at 35 DAS

4.2: Summer season:

Weed flora differ in different seasons and at different sites. The summer season experiment was conducted over well-established lawn at three different locations to find out the effective weed control method in lawn by chemical weed management approaches. Major weed flora during this season among grasses were *Digitaria sanguinalis*, *Dicanthium annulatum*, *Dactyloctenium aegyptium* and *Paspalum dilatatum*. *Boerhavia diffusa*, *Alysicarpus vaginalis*, *Evolvulus nummularius* and *Desmodium triflorum* were observed among broadleaf weeds and *Cyperus rotundus* as sedges. The density of grasses was 59.2 per cent, broadleaf weeds was 34.4 per cent and sedges was 6.4 per cent.

4.2.1: *Digitaria sanguinalis* density

Digitaria sanguinalis density before spray of herbicides ranged between 56-78 m^{-2} at Location IV whereas this range was 44 to 66 m^{-2} at Location V (Table 4.2.1.). The density difference was non-significant at all the locations before the spray of post-emergence herbicides. This weed did not appear at the sixth location.

The density observed 15 days after the spray of different post-emergence herbicides indicated that hand weeded treatment at 15 DAS provided complete control of this weed and was significantly lower as compared with all other weed control treatments and weedy check. The second-best herbicide observed was clodinafop + metribuzin @ 0.216 kg ha^{-1} and metribuzin @ 0.120 kg ha^{-1} which helped to reduce the weed density as compared with other weed control treatments. The perusal of the density (Table 4.2.2.) indicated that hand weeded treatment provided complete control upto 60 DAS of this weed and the weed density was significantly lower as compared with all other weed control treatments and weedy check. The second-best treatment was clodinafop + metribuzin @ 0.216 kg ha^{-1} and it was at par with metribuzin @ 0.120 kg ha^{-1}.

Table 4.2.1: *Digitaria sanguinalis* periodic density before and after spray of post-emergence herbicides at different locations in lawn during summer season

Treatments	Dose (kg ha^{-1})	*Digitaria sanguinalis* density (No. m^{-2})			
		Before spray		15 DAS	
		Location IV	Location V	Location IV	Location V
Isoproturon	0.937	56	44	8.25^{cd} (67)	7.48^{cd} (55)
Mesosulfuron + Iodosulfuron	0.014	78	66	8.89^{cd} (78)	8.19^{cd} (66)
Clodinafop + Metribuzin	0.216	67	55	5.83^{b} (33)	4.69^{b} (21)
2,4-D amine	0.500	56	44	8.25^{cd} (67)	7.48^{cd} (55)
Bispyribac sodium	0.025	78	66	9.49^{d} (89)	8.83^{d} (77)
Metribuzin	0.120	67	55	7.55^{bc} (56)	6.71^{bc} (44)
Metsulfuron	0.005	56	44	8.25^{cd} (67)	7.48^{cd} (55)
Carfentrazone-ethyl	0.020	56	44	8.25^{cd} (67)	7.48^{cd} (55)
Metsulfuron + Carfentrazone-ethyl	0.025	78	66	9.49^{d} (89)	8.83^{d} (77)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	67	55	8.89^{cd} (78)	8.19^{cd} (66)
Ethoxysulfuron	0.018	56	44	8.89^{cd} (78)	6.71^{cd} (44)
Halosulfuron	0.050	78	66	9.49^{d} (89)	8.83^{d} (77)
Atrazine	1.000	67	55	8.89^{cd} (78)	8.19^{cd} (66)
Two hand weedings (15 days interval)	-	56	44	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	78	66	9.49^{d} (89)	8.83^{d} (77)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

Table 4.2.2: Effect of post-emergence herbicides on periodic *Digitaria sanguinalis* density at different locations in lawn

Treatments	Dose (kg ha^{-1})	*Digitaria sanguinalis* density (No. m^{-2})					
		30 DAS		45 DAS		60 DAS	
		Location IV	Location V	Location IV	Location V	Location IV	Location V
Isoproturon	0.937	8.25^{cd} (67)	8.19^{cde} (66)	8.89^{cde} (78)	8.19^{cde} (66)	8.25^{cde} (67)	8.19^{cde} (66)
Mesosulfuron + Iodosulfuron	0.014	8.89^{cd} (78)	8.83^{de} (77)	9.49^{de} (89)	8.83^{de} (77)	8.89^{de} (78)	8.83^{de} (77)
Clodinafop + Metribuzin	0.216	5.83^{b} (33)	4.69^{b} (21)	5.83^{b} (33)	4.69^{b} (21)	4.80^{b} (22)	4.69^{b} (21)
2,4-D amine	0.500	8.25^{cd} (67)	8.19^{cde} (66)	8.89^{cde} (78)	8.19^{cde} (66)	8.25^{cde} (67)	8.19^{cde} (66)
Bispyribac sodium	0.025	9.49^{d} (89)	8.83^{de} (77)	9.49^{de} (89)	8.83^{de} (77)	8.89^{de} (78)	8.83^{de} (77)
Metribuzin	0.120	7.55^{bc} (56)	6.71^{bc} (44)	7.55^{bc} (56)	6.71^{bc} (44)	6.71^{bc} (44)	6.71^{bc} (44)
Metsulfuron	0.005	8.25^{cd} (67)	8.19^{cde} (66)	8.89^{cde} (78)	8.19^{cde} (66)	8.25^{cde} (67)	8.19^{cde} (66)
Carfentrazone-ethyl	0.020	8.25^{cd} (67)	8.19^{cde} (66)	8.89^{cde} (78)	8.19^{cde} (66)	8.25^{cde} (67)	8.19^{cde} (66)
Metsulfuron + Carfentrazone-ethyl	0.025	9.49^{d} (89)	9.43^{d} (88)	10.05^{d} (100)	9.43^{d} (88)	9.49^{e} (89)	9.43^{d} (88)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	8.89^{cd} (78)	8.83^{de} (77)	9.49^{de} (89)	8.83^{de} (77)	8.89^{de} (78)	8.83^{de} (77)
Ethoxysulfuron	0.018	8.89^{cd} (78)	7.48^{cd} (55)	9.49^{de} (89)	7.48^{cd} (55)	8.89^{de} (78)	7.48^{cd} (55)
Halosulfuron	0.050	9.49^{d} (89)	9.43^{d} (88)	10.05^{d} (100)	9.43^{d} (88)	9.49^{e} (89)	9.43^{d} (88)
Atrazine	1.000	8.89^{cd} (78)	8.83^{de} (77)	9.49^{de} (89)	8.83^{de} (77)	8.89^{de} (78)	8.83^{de} (77)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	9.49^{d} (89)	9.43^{d} (88)	10.05^{d} (100)	9.43^{d} (88)	10.05^{e} (100)	9.43^{d} (88)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

Table 4.2.3: *Dicanthium annulatum* density before and after spray of post-emergence herbicides at different locations in lawn during summer season

Treatments	Dose (kg ha^{-1})	*Dicanthium annulatum* density (No. m^{-2})			
		Before spray		15 DAS	
		Location V	Location VI	Location V	Location VI
Isoproturon	0.937	56	56	8.25^{d} (67)	8.31^{de} (68)
Mesosulfuron + Iodosulfuron	0.014	67	56	6.71^{bc} (44)	6.71^{bc} (44)
Clodinafop + Metribuzin	0.216	67	67	5.83^{b} (33)	4.80^{b} (22)
2,4-D amine	0.500	78	44	9.49^{d} (89)	7.62^{de} (57)
Bispyribac sodium	0.025	78	56	1.00^{a} (0)	1.00^{a} (0)
Metribuzin	0.120	67	44	8.25^{d} (67)	6.71^{cd} (44)
Metsulfuron	0.005	67	56	8.89^{d} (78)	8.31^{de} (68)
Carfentrazone-ethyl	0.020	56	67	8.89^{d} (78)	8.94^{e} (79)
Metsulfuron + Carfentrazone-ethyl	0.025	67	44	8.89^{d} (78)	7.62^{de} (57)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	78	56	9.49^{d} (89)	8.31^{de} (68)
Ethoxysulfuron	0.018	78	44	8.89^{d} (78)	7.48^{de} (55)
Halosulfuron	0.050	67	44	8.89^{d} (78)	7.48^{de} (55)
Atrazine	1.000	56	56	8.25^{d} (67)	8.31^{de} (68)
Two hand weedings (15 days interval)	-	67	56	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	56	56	9.49^{d} (89)	8.31^{de} (68)

*Values in the parentheses are original means. Data was subjected to square root transformation √(x+1)

4.2.2: *Dicanthium annulatum* density

Dicanthium annulatum density before and after the application of different post-emergence herbicides at different locations are presented in Table 4.2.3. The number of plants of *Dicanthium annulatum* ranged between 56 to 78 m^{-2} at Location V whereas this range was 44 to 67 m^{-2} at Location VI. The difference in the density of *Dicanthium annulatum* was non-significant at all the locations before the application of different herbicides. This weed did not appear at Location IV.

The density of *Dicanthium annulatum* as recorded 15 DAS indicated that bispyribac sodium @ 0.025 kg ha^{-1} and two hand weeding treatments provided complete control of this weed and was significantly lower as compared with all other weed control treatments and weedy check at both the locations. Clodinafop + metribuzin @ 0.216 kg ha^{-1} and mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1} were at par with each other and helped to reduce the population of this weed significantly as compared with weedy check. The perusal of the density indicated that bispyribac sodium @ 0.025 kg ha^{-1} and two hand weedings provided complete control upto

45 DAS of this weed and was significantly lower as compared with all other weed control treatments and weedy check at both the locations (Table 4.2.4.). Re-sprouting of this weed was observed in two hand weedings when observed at 60 DAS but bispyribac sodium @ 0.025 kg ha^{-1} proved to be the best treatment for the control of this weed.

Table 4.2.4: Effect of post-emergence herbicides on periodic *Dicanthium annulatum* density at different locations in lawn

Treatments	Dose (kg ha^{-1})	*Dicanthium annulatum* density (No. m^{-2})					
		30 DAS		45 DAS		60 DAS	
		Location V	Location VI	Location V	Location VI	Location V	Location VI
Isoproturon	0.937	9.17^{d} (83)	8.94^{de} (79)	9.49^{d} (89)	9.38^{de} (87)	9.85^{d} (96)	9.38^{de} (87)
Mesosulfuron + Iodosulfuron	0.014	7.87^{bc} (61)	5.92^{bc} (34)	8.25^{bc} (67)	6.56^{bc} (42)	8.60^{bc} (73)	6.56^{bc} (42)
Clodinafop + Metribuzin	0.216	5.83^{b} (33)	5.83^{b} (33)	6.32^{b} (39)	6.48^{b} (41)	6.86^{b} (46)	6.48^{b} (41)
2,4-D amine	0.500	10.34^{d} (106)	8.31^{de} (68)	10.34^{d} (106)	8.77^{de} (76)	10.34^{d} (106)	8.77^{de} (76)
Bispyribac sodium	0.025	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metribuzin	0.120	9.17^{d} (83)	7.55^{cd} (56)	9.49^{d} (89)	8.00^{cd} (63)	9.85^{d} (96)	8.00^{cd} (63)
Metsulfuron	0.005	9.75^{d} (94)	8.94^{de} (79)	10.05^{d} (100)	9.38^{de} (87)	10.39^{d} (107)	9.38^{de} (87)
Carfentrazone-ethyl	0.020	9.17^{d} (83)	8.94^{de} (79)	9.49^{d} (89)	9.48^{de} (89)	9.85^{d} (96)	9.48^{de} (89)
Metsulfuron + Carfentrazone-ethyl	0.025	9.75^{d} (94)	8.31^{de} (68)	10.05^{d} (100)	8.77^{de} (76)	10.39^{d} (107)	8.77^{de} (76)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	10.34^{d} (106)	8.94^{de} (79)	10.58^{d} (111)	9.38^{de} (87)	10.91^{d} (118)	9.38^{de} (87)
Ethoxysulfuron	0.018	9.75^{d} (94)	8.00^{de} (63)	10.05^{d} (100)	8.49^{cde} (71)	10.39^{d} (107)	8.49^{de} (71)
Halosulfuron	0.050	9.75^{d} (94)	8.19^{de} (66)	10.05^{d} (100)	8.60^{de} (73)	10.39^{d} (107)	8.60^{de} (73)
Atrazine	1.000	9.17^{d} (83)	8.94^{de} (79)	9.49^{d} (89)	9.38^{de} (87)	9.80^{d} (96)	9.38^{de} (87)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	4.00^{a} (15)	5.2^{ab} (26)
Un-weeded (control)	-	10.34^{d} (106)	8.94^{de} (79)	10.34^{d} (106)	9.38^{de} (87)	10.34^{d} (106)	9.38^{de} (87)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

Table 4.2.5: *Dactyloctenium aegyptium* density before and after the spray of post-emergence herbicides at Location IV in lawn during summer season

Treatments	Dose (kg ha^{-1})	*Dactyloctenium aegyptium* density (No. m^{-2})				
		Before spray	15 DAS	30 DAS	45 DAS	60 DAS
Isoproturon	0.937	44	6.71^{bc} (44)	7.55^{bc} (56)	7.55^{bc} (56)	7.55^{bc} (56)
Mesosulfuron + Iodosulfuron	0.014	33	6.71^{bc} (44)	7.55^{bc} (56)	7.55^{bc} (56)	7.55^{bc} (56)
Clodinafop + Metribuzin	0.216	22	3.94^{ab} (15)	3.94^{ab} (15)	5.20^{ab} (26)	5.20^{ab} (26)
2,4-D amine	0.500	44	7.55^{c} (56)	8.25^{c} (67)	8.25^{c} (67)	8.25^{c} (67)
Bispyribac sodium	0.025	33	5.2^{bc} (26)	6.16^{bc} (37)	6.16^{bc} (37)	6.16^{bc} (37)
Metribuzin	0.120	33	5.83^{bc} (33)	6.71^{bc} (44)	6.71^{bc} (44)	6.71^{bc} (44)
Metsulfuron	0.005	44	7.55^{c} (56)	8.25^{c} (67)	8.25^{c} (67)	8.25^{c} (67)
Carfentrazone-ethyl	0.020	33	6.71^{bc} (44)	7.55^{bc} (56)	7.55^{bc} (56)	7.55^{bc} (56)
Metsulfuron + Carfentrazone-ethyl	0.025	22	5.83^{bc} (33)	6.71^{bc} (44)	6.71^{bc} (44)	6.71^{bc} (44)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	44	7.55^{c} (56)	8.25^{c} (67)	8.25^{c} (67)	8.25^{c} (67)
Ethoxysulfuron	0.018	44	7.55^{c} (56)	8.25^{c} (67)	8.25^{c} (67)	8.25^{c} (67)
Halosulfuron	0.050	33	6.71^{bc} (44)	7.55^{bc} (56)	7.55^{bc} (56)	7.55^{bc} (56)
Atrazine	1.000	44	7.55^{c} (56)	8.25^{c} (67)	8.25^{c} (67)	8.25^{c} (67)
Two hand weedings (15 days interval)	-	22	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	44	7.55^{c} (56)	8.25^{c} (67)	8.25^{c} (67)	8.25^{c} (67)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.2.3: *Dactyloctenium aegyptium* density

Dactyloctenium aegyptium density before and after the spray of different post-emergence herbicides during summer season at Location IV are presented in Table 4.2.5. The number of plants of this weed ranged between 22 to 44 m^{-2}. The difference in the density of *Dactyloctenium aegyptium* was non-significant before the application of different herbicides. This weed did not appear at other two locations.

At 15 DAS, the lowest weed density was recorded in hand weeding treatment which was statistically at par with clodinafop + metribuzin @ 0.216 kg ha^{-1} and significantly lower as compared with other weed control treatments and weedy check. The hand weeding treatment gave complete control of this weed upto 60 DAS. Re-sprouting of this weed was observed in clodinafop + metribuzin @ 0.216 kg ha^{-1} when observed at 45 DAS.

Table 4.2.6: Periodic density of *Paspalum dilatatum* before and after the spray of post-emergence herbicides at Location VI in lawn

Treatments	Dose (kg ha^{-1})	*Paspalum dilatatum* density (No. m^{-2})				
		Before spray	15 DAS	30 DAS	45 DAS	60 DAS
Isoproturon	0.937	5	2.65^{cd} (6)	2.83^{d} (7)	2.83^{cd} (7)	2.83^{cd} (7)
Mesosulfuron + Iodosulfuron	0.014	6	1.73^{ab} (2)	1.73^{ab} (2)	2.00^{ab} (3)	2.00^{ab} (3)
Clodinafop + Metribuzin	0.216	5	2.24^{bc} (4)	2.24^{bc} (4)	2.45^{bc} (5)	2.45^{bc} (5)
2,4-D amine	0.500	6	2.83^{d} (7)	3.00^{d} (8)	3.00^{d} (8)	3.00^{d} (8)
Bispyribac sodium	0.025	5	2.65^{cd} (6)	2.83^{d} (7)	2.83^{cd} (7)	2.83^{cd} (7)
Metribuzin	0.120	4	2.45^{cd} (5)	2.65^{cd} (6)	2.65^{cd} (6)	2.65^{cd} (6)
Metsulfuron	0.005	5	2.65^{cd} (6)	2.83^{d} (7)	2.83^{cd} (7)	2.83^{cd} (7)
Carfentrazone-ethyl	0.020	6	2.83^{d} (7)	3.00^{d} (8)	3.00^{d} (8)	3.00^{d} (8)
Metsulfuron + Carfentrazone-ethyl	0.025	4	2.45^{cd} (5)	2.65^{cd} (6)	2.65^{cd} (6)	2.65^{cd} (6)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	5	2.65^{cd} (6)	2.83^{d} (7)	2.83^{cd} (7)	2.83^{cd} (7)
Ethoxysulfuron	0.018	5	2.65^{cd} (6)	2.83^{d} (7)	2.83^{cd} (7)	2.83^{cd} (7)
Halosulfuron	0.050	4	2.45^{cd} (5)	2.65^{cd} (6)	2.65^{cd} (6)	2.65^{cd} (6)
Atrazine	1.000	5	2.65^{cd} (6)	2.83^{d} (7)	2.83^{cd} (7)	2.83^{cd} (7)
Two hand weedings (15 days interval)	-	6	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.73^{a} (2)
Un-weeded (control)	-	6	2.83^{d} (7)	3.00^{d} (8)	3.00^{d} (8)	3.00^{d} (8)

*Values in the parentheses are original means. Data was subjected to square root transformation √(x+1)

	
Before spray	15 DAS

Plate 5: Effect of bispyribac sodium spray on *Dicanthium annulatum*

	
Before spray	15 DAS

Plate 6: Effect of mesosulfuron + iodosulfuron spray on *Paspalum dilatatum*

4.2.4: *Paspalum dilatatum* density

Paspalum dilatatum density before and after the application of herbicide spray at Location VI are presented in Table 4.2.6. The number of plants of *Paspalum dilatatum* ranged between 4 to 6 m^{-2}. The difference in the density of *Paspalum dilatatum* was non-significant before the spray of different herbicides. This weed did not appear at other two locations.

At 15 DAS, the lowest weed density was recorded in hand weeding which was significantly lower as compared with all other weed control treatments and weedy check. The density of this weed as affected by mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1} and was at par with hand weeding. Similar trend was observed in the later observations. There was re-sprouting of this weed in mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1} when observed after 45 DAS and two hand weedings provided complete control upto 60 DAS.

4.2.5: *Boerhavia diffusa* density

Boerhavia diffusa density before and after the spray of post-emergence herbicicdes during summer season at Location IV are presented in Table 4.2.7. The number of plants of *Boerhavia diffusa* ranged between 11 to 22 m^{-2} at Location IV however this weed did not appear at other two locations. The difference in the density of *Boerhavia diffusa* was non-significant before the application of different herbicides.

The density revealed that metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and two hand weedings provided complete control upto 60 DAS of this weed as compared with all other herbicides and weedy check. Isoproturon @ 0.937 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1} and metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1} proved to the second-best group of herbicides for the control of this weed effectively.

Table 4.2.7: *Boerhavia diffusa* density before and after the spray of post-emergence herbicides at Location IV in lawn during summer season

Treatments	Dose (kg ha^{-1})	*Boerhavia diffusa* density (No. m^{-2})				
		Before spray	15 DAS	30 DAS	45 DAS	60 DAS
Isoproturon	0.937	22	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)
Mesosulfuron + Iodosulfuron	0.014	11	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)
Clodinafop + Metribuzin	0.216	22	4.80^{c} (22)	4.80^{c} (22)	4.80^{c} (22)	4.80^{c} (22)
2,4-D amine	0.500	11	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)
Bispyribac sodium	0.025	22	4.80^{c} (22)	4.80^{c} (22)	4.80^{c} (22)	4.80^{c} (22)
Metribuzin	0.120	22	4.80^{c} (22)	4.80^{c} (22)	4.80^{c} (22)	4.80^{c} (22)
Metsulfuron	0.005	22	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)
Carfentrazone-ethyl	0.020	11	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)
Metsulfuron + Carfentrazone-ethyl	0.025	22	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	22	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)
Ethoxysulfuron	0.018	11	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)
Halosulfuron	0.050	22	4.80^{c} (22)	4.80^{c} (22)	4.80^{c} (22)	4.80^{c} (22)
Atrazine	1.000	22	4.80^{c} (22)	4.80^{c} (22)	4.80^{c} (22)	4.80^{c} (22)
Two hand weedings (15 days interval)	-	11	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	22	4.80^{c} (22)	4.80^{c} (22)	4.80^{c} (22)	4.80^{c} (22)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.2.6: *Alysicarpus vaginalis* density

Alysicarpus vaginalis density before application of different herbicides at Location IV during summer season ranged between 44 to 67 m^{-2} however, this weed did not appear at other two locations. The difference in the density of *Alysicarpus vaginalis* was non-significant before the spray of different post-emergence herbicides (Table 4.2.8.).

The density when observed at 15 DAS revealed that hand weeding, metsulfuron @ 0.005 kg ha^{-1} and metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} provided significantly

	
Before spray	7 DAS

Plate 7: Effect of metsulfuron + carfentrazone-ethyl spray on *Boerhavia diffusa*

	
Before spray	7 DAS

Plate 8: Effect of metsulfuron + carfentrazone-ethyl spray on *Alysicarpus vaginalis*

lower population of this weed as compared with other weed control treatments and weedy check except metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1} and carfentrazone-ethyl @ 0.025 kg ha^{-1} which were at par with these treatments. All these treatments gave complete control of this weed upto 60 DAS.

Table 4.2.8: *Alysicarpus vaginalis* density before and after the spray of post-emergence herbicides at Location IV in lawn during summer season

Treatments	Dose (kg ha^{-1})	*Alysicarpus vaginalis* density (No. m^{-2})				
		Before spray	15 DAS	30 DAS	45 DAS	60 DAS
Isoproturon	0.937	44	7.55^{bc} (56)	8.25^{b} (67)	8.25^{b} (67)	8.25^{b} (67)
Mesosulfuron + Iodosulfuron	0.014	67	8.89^{c} (78)	9.49^{c} (89)	9.49^{c} (89)	9.49^{c} (89)
Clodinafop + Metribuzin	0.216	56	8.25^{c} (67)	8.89^{c} (78)	8.89^{c} (78)	8.89^{c} (78)
2,4-D amine	0.500	56	8.25^{c} (67)	8.89^{c} (78)	8.89^{c} (78)	8.89^{c} (78)
Bispyribac sodium	0.025	44	8.00^{c} (63)	8.25^{b} (67)	8.25^{b} (67)	8.25^{b} (67)
Metribuzin	0.120	56	8.25^{c} (67)	8.89^{c} (78)	8.89^{c} (78)	8.89^{c} (78)
Metsulfuron	0.005	67	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Carfentrazone-ethyl	0.020	56	5.48^{ab} (29)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron + Carfentrazone-ethyl	0.025	44	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	56	4.79^{ab} (22)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Ethoxysulfuron	0.018	44	7.55^{bc} (56)	8.25^{b} (67)	8.25^{b} (67)	8.25^{b} (67)
Halosulfuron	0.050	56	8.25^{c} (67)	8.89^{c} (78)	8.89^{c} (78)	8.89^{c} (78)
Atrazine	1.000	67	8.25^{c} (67)	8.89^{c} (78)	8.89^{c} (78)	8.89^{c} (78)
Two hand weedings (15 days interval)	-	44	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	67	8.89^{c} (78)	9.49^{c} (89)	9.49^{c} (89)	9.49^{c} (89)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

Table 4.2.9: ***Evolvulus nummularius*** **density before and after the spray of post-emergence herbicides at Location V in lawn**

Treatments	**Dose (kg ha^{-1})**	***Evolvulus nummularius*** **density (No. m^{-2})**				
		Before spray	15 DAS	30 DAS	45 DAS	60 DAS
Isoproturon	0.937	29	5.83^{b} (33)	5.83^{b} (33)	5.83^{b} (33)	5.83^{a} (33)
Mesosulfuron + Iodosulfuron	0.014	22	4.80^{b} (22)	4.80^{b} (22)	4.80^{b} (22)	4.80^{a} (22)
Clodinafop + Metribuzin	0.216	22	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)	4.80^{a} (22)
2,4-D amine	0.500	22	4.80^{b} (22)	4.80^{b} (22)	4.80^{b} (22)	4.80^{a} (22)
Bispyribac sodium	0.025	22	4.80^{b} (22)	4.80^{b} (22)	4.80^{b} (22)	4.80^{a} (22)
Metribuzin	0.120	33	5.83^{b} (33)	5.83^{b} (33)	5.83^{b} (33)	5.83^{a} (33)
Metsulfuron	0.005	33	5.83^{b} (33)	5.83^{b} (33)	5.83^{b} (33)	5.83^{a} (33)
Carfentrazone-ethyl	0.020	22	3.46^{b} (11)	3.46^{b} (11)	4.80^{b} (22)	4.80^{a} (22)
Metsulfuron + Carfentrazone-ethyl	0.025	22	3.46^{b} (11)	3.46^{b} (11)	3.46^{b} (11)	4.80^{a} (22)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	33	5.83^{b} (33)	5.83^{b} (33)	5.83^{b} (33)	5.83^{a} (33)
Ethoxysulfuron	0.018	29	5.83^{b} (33)	5.83^{b} (33)	5.83^{b} (33)	5.83^{a} (33)
Halosulfuron	0.050	22	4.80^{b} (22)	4.80^{b} (22)	4.80^{b} (22)	4.80^{a} (22)
Atrazine	1.000	33	4.80^{b} (22)	4.80^{b} (22)	4.80^{b} (22)	4.80^{a} (22)
Two hand weedings (15 days interval)	-	29	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	4.80^{a} (22)
Un-weeded (control)	-	33	5.83^{b} (33)	5.83^{b} (33)	5.83^{b} (33)	5.83^{a} (33)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.2.7: ***Evolvulus nummularius*** **density**

Evolvulus nummularius density before spray of post-emergence herbicides ranged between 22 to 33 m^{-2} at Location V however, this weed did not appear at other two locations (Table 4.2.9.). *Evolvulus nummularius* density difference was non-significant before the application of different herbicides.

The density of *Evolvulus nummularius* as observed 15 DAS indicated that hand weeding provided complete control of this weed and was significantly lower as compared with all other herbicides and weedy check. This treatment gave complete control upto 45 DAS and there was re-sprouting when observed at 60 DAS.

Table 4.2.10: *Desmodium triflorum* density before and after the spray of post-emergence herbicides at Location VI in lawn during summer season

Treatments	**Dose (kg ha^{-1})**	***Desmodium triflorum* density (No. m^{-2})**				
		Before spray	15 DAS	30 DAS	45 DAS	60 DAS
Isoproturon	0.937	33	6.86^{bc} (46)	7.55^{bc} (56)	8.19^{bc} (66)	8.19^{bc} (66)
Mesosulfuron + Iodosulfuron	0.014	33	6.86^{bc} (46)	7.55^{bc} (56)	8.19^{bc} (66)	8.19^{bc} (66)
Clodinafop + Metribuzin	0.216	44	5.83^{b} (33)	6.63^{b} (43)	7.35^{b} (53)	7.35^{b} (53)
2,4-D amine	0.500	54	6.71^{bc} (44)	7.50^{bc} (56)	7.50^{bc} (56)	7.50^{bc} (56)
Bispyribac sodium	0.025	56	8.31^{c} (68)	8.89^{c} (78)	9.43^{c} (88)	9.43^{c} (88)
Metribuzin	0.120	44	6.16^{b} (37)	6.93^{b} (47)	7.62^{b} (57)	7.62^{b} (57)
Metsulfuron	0.005	44	6.16^{b} (37)	6.93^{b} (47)	7.62^{b} (57)	7.62^{b} (57)
Carfentrazone-ethyl	0.020	56	6.71^{bc} (44)	7.42^{bc} (54)	8.06^{bc} (64)	8.06^{bc} (64)
Metsulfuron + Carfentrazone-ethyl	0.025	56	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	44	5.83^{b} (33)	6.63^{b} (43)	7.35^{b} (53)	7.35^{b} (53)
Ethoxysulfuron	0.018	56	8.31^{c} (68)	8.31^{c} (68)	8.89^{c} (78)	8.89^{c} (78)
Halosulfuron	0.050	33	6.86^{bc} (46)	7.55^{bc} (56)	8.19^{bc} (66)	8.19^{bc} (66)
Atrazine	1.000	44	6.71^{bc} (44)	7.35^{bc} (53)	7.35^{b} (53)	7.35^{b} (53)
Two hand weedings (15 days interval)	-	56	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	4.69^{a} (21)
Un-weeded (control)	-	56	8.31^{c} (68)	8.89^{c} (78)	9.43^{c} (88)	9.43^{c} (88)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.2.8: *Desmodium triflorum* density

Desmodium triflorum density before and after the spray of different post-emergence of herbicides at location VI are presented in Table 4.2.10. The number of plants of *Desmodium triflorum* ranged between 33 to 56 m^{-2} however, this weed did not appear at other locations. *Desmodium triflorum* density was non-significant before the application of different herbicides.

The density as recorded at 15 DAS showed the lowest density in metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and two hand weeding and provided complete control when observed upto 45 DAS and was significantly lower as compared with all other herbicides and weedy check. The second-best herbicides were clodinafop + metribuzin @ 0.216 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1} and metsulfuron + chlorimuron-ethyl @ 0.004 kg ha^{-1} which helped to reduce the weed density. There was re-sprouting of *Desmodium triflorum* in clodinafop + metribuzin @ 0.216 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1} and metsulfuron + chlorimuron-ethyl @ 0.004 kg ha^{-1} after 30 days of spray whereas resprouting was observed in metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and two hand weedings at 60 DAS.

4.2.9: *Cyperus rotundus* density

Cyperus rotundus density before and after the application of different herbicides at location IV are presented in Table 4.2.11. The number of plants of *Cyperus rotundus* ranged between 22 to 44 m^{-2} however, this weed did not appear at other two locations. The difference in the density of *Cyperus rotundus* was non-significant as the density was recorded before the application of different post-emergence herbicides during summer season.

The density of *Cyperus rotundus* as recorded at 15 DAS showed the lowest density in ethoxysulfuron @ 0.018 kg ha^{-1}, halosulfuron @ 0.050 kg ha^{-1} and hand weeding treatment which was significantly lower than all other post-emergence herbicides and unweeded check. 2,4-D amine @ 0.5 kg ha^{-1} proved to be the second-best herbicide for the control of this weed. Halosulfuron @ 0.050 kg ha^{-1} provided complete control upto 45 DAS and the re-sprouting of *Cyperus rotundus observed* at 60 DAS whereas re-sprouting in ethoxysulfuron @ 0.018 kg ha^{-1} and hand weeding treatment when observed at 45 DAS. McCarty *et al* (2008) also reported that *Cyperus rotundus* density significantly got reduced with the spray of herbicide Halosulfuron-methyl. This weed did not appear at other two locations.

	
Before spray	15 DAS

Plate 9: Effect of halosulfuron spray on *Cyperus rotundus*

Table 4.2.11: *Cyperus rotundus* density before and after the spray of different post-emergence herbicides at Location IV in lawn during summer season

Treatments	Dose (kg ha^{-1})	*Cyperus rotundus* density (No. m^{-2})				
		Before spray	15 DAS	30 DAS	45 DAS	60 DAS
Isoproturon	0.937	33	5.83^{b} (33)	6.71^{c} (44)	7.55^{cd} (56)	7.55^{cd} (56)
Mesosulfuron + Iodosulfuron	0.014	33	5.83^{b} (33)	6.71^{c} (44)	7.55^{cd} (56)	7.55^{cd} (56)
Clodinafop + Metribuzin	0.216	44	6.71^{b} (44)	7.55^{c} (56)	8.25^{d} (67)	8.25^{d} (67)
2,4-D amine	0.500	33	4.36^{ab} (18)	5.2^{ab} (26)	6.16^{bc} (37)	7.55^{cd} (56)
Bispyribac sodium	0.025	33	5.83^{b} (33)	6.71^{c} (44)	7.55^{cd} (56)	7.55^{cd} (56)
Metribuzin	0.120	44	6.71^{b} (44)	7.55^{c} (56)	8.25^{d} (67)	8.25^{d} (67)
Metsulfuron	0.005	33	5.83^{b} (33)	6.71^{c} (44)	7.55^{cd} (56)	7.55^{cd} (56)
Carfentrazone-ethyl	0.020	44	6.71^{b} (44)	7.55^{c} (56)	8.25^{d} (67)	8.25^{d} (67)
Metsulfuron + Carfentrazone-ethyl	0.025	44	6.71^{b} (44)	7.55^{c} (56)	8.25^{d} (67)	8.25^{d} (67)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	44	6.71^{b} (44)	7.55^{c} (56)	8.25^{d} (67)	8.25^{d} (67)
Ethoxysulfuron	0.018	44	1.00^{a} (0)	1.00^{a} (0)	4.00^{ab} (15)	5.2^{ab} (26)
Halosulfuron	0.050	22	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	4.00^{a} (15)
Atrazine	1.000	44	6.71^{b} (44)	7.55^{c} (56)	8.25^{d} (67)	8.25^{d} (67)
Two hand weedings (15 days interval)	-	44	1.00^{a} (0)	1.00^{a} (0)	4.36^{ab} (18)	5.2^{ab} (26)
Un-weeded (control)	-	33	5.83^{b} (33)	6.71^{c} (44)	7.55^{cd} (56)	7.55^{cd} (56)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.2.10: Fresh weight of weeds before the herbicide spray in lawn

The fresh weight of grasses, broadleaf and sedges before the spray of different herbicides at different locations are presented in Table 4.2.12. The fresh weight of grass weeds ranged between 434.97 g to 508.80 g m^{-2} at Location IV, whereas this range was 101.67 g to 124.77 g m^{-2} and 204.43 g to 243.3 g m^{-2} at Location V and Location VI, respectively. The range of broadleaf weed was 147.0 g to 176.77 g, 38.9 g to 45.6 g and 37.80 g to 51.1 g m^{-2} at

Location IV, Location V and Location VI, respectively. In sedges, the range was 43.3 g to 51.1 g m^{-2} at location IV. However, sedge weeds did not appear at other locations. The difference in the fresh weight of different categories of weeds was non-significant as the data was recorded before the application of different post-emergence herbicides.

Table 4.2.12: Fresh weight of weeds before the spray of different post-emergence herbicides at different locations in lawn during summer season

Treatments	Fresh weight (g m^{-2})						
	Grasses			Broadleaf			Sedges
	Location IV	Location V	Location VI	Location IV	Location V	Location VI	Location IV
Isoproturon	508.75	113.30	227.77	150.67	38.90	38.90	50.00
Mesosulfuron + Iodosulfuron	491.10	109.77	239.97	160.53	43.30	50.00	44.40
Clodinafop + Metribuzin	457.70	110.00	219.97	171.63	45.60	46.70	46.70
2,4-D amine	470.40	117.10	208.87	156.87	38.90	51.10	47.80
Bispyribac sodium	442.97	124.77	232.20	158.10	40.00	43.30	50.00
Metribuzin	435.20	104.00	236.63	151.43	41.10	46.70	50.00
Metsulfuron	458.10	113.43	233.30	161.43	43.30	42.20	48.90
Carfentrazone-ethyl	472.20	116.10	209.97	173.63	44.40	37.80	44.40
Metsulfuron + Carfentrazone-ethyl	508.80	106.00	228.87	169.00	45.60	45.57	43.30
Metsulfuron-methyl + Chlorimuron-ethyl	434.97	106.67	237.77	148.00	41.10	46.70	43.30
Ethoxysulfuro n	457.60	109.00	229.97	147.00	45.60	47.80	45.60
Halosulfuron	494.20	115.67	218.87	176.77	38.90	38.90	46.70
Atrazine	483.70	113.67	216.63	167.87	42.20	40.00	43.30
Two hand weedings (15 days interval)	468.50	101.67	243.30	148.77	43.30	37.80	50.00
Un-weeded (control)	483.60	104.77	204.43	168.20	44.40	50.00	51.10

Table 4.2.13: Dry weight of weeds before the spray of different post-emergence herbicides at different locations in lawn during summer season

Treatments	Dry weight (g m^{-2})						
	Grasses			Broadleaf			Sedges
	Location IV	Location V	Location VI	Location IV	Location V	Location VI	Location IV
Isoproturon	127.20	28.30	56.93	37.67	9.70	9.71	12.50
Mesosulfuron + Iodosulfuron	122.77	27.40	60.00	40.13	10.80	12.50	11.10
Clodinafop + Metribuzin	114.43	27.50	55.00	42.90	11.40	11.67	11.70
2,4-D amine	117.60	29.30	52.20	39.23	9.70	12.80	11.90
Bispyribac sodium	110.73	31.20	58.03	39.53	10.00	10.83	12.50
Metribuzin	108.80	26.00	59.17	37.87	10.30	11.67	12.50
Metsulfuron	114.50	28.40	58.33	40.37	10.80	10.57	12.20
Carfentrazone-ethyl	118.03	29.00	52.50	43.40	11.10	9.43	11.10
Metsulfuron + Carfentrazone-ethyl	127.20	26.50	57.20	42.23	11.40	11.40	10.80
Metsulfuron-methyl + Chlorimuron-ethyl	108.73	26.70	59.43	37.00	10.30	11.67	10.80
Ethoxysulfuron	114.40	27.23	57.50	36.73	11.40	11.93	11.40
Halosulfuron	123.53	28.90	54.70	44.20	9.70	9.70	11.70
Atrazine	120.93	28.40	54.17	41.97	10.60	10.00	10.80
Two hand weedings (15 days interval)	117.10	25.40	60.83	37.20	10.80	9.43	12.50
Un-weeded (control)	120.90	26.20	51.10	42.07	11.10	12.50	12.80

4.2.11: Dry weight of weeds before the spray of herbicides during summer season

The dry weight of grasses, broadleaf and sedges before the application of different herbicides at different locations during summer season are presented in Table 4.2.13. The dry weight of grasses ranged between 108.73 g to 127.20 g m^{-2} at Location IV, whereas this range was 25.4 g to 31.2 g and 51.1 g to 60.83 g m^{-2} at Location V and Location VI, respectively. The dry weight of broadleaf weeds ranged between 36.73 g to 44.2 g, 9.7 g to 11.4 g and 9.43 g to 12.8 g m^{-2} at Location IV, Location V and location VI, respectively. In sedges, this range was 10.8 g to 12.8 g m^{-2} at location IV. However, sedges did not appear at other two locations. The difference in the dry weight of different categories weeds was non-significant as the weight was recorded before the spray of different post-emergence herbicides in lawn.

Table 4.2.14: Effect of post-emergence herbicides on periodic dry weight of grass weeds at different locations 15 and 30 DAS in lawn during summer season

Treatments	Dose (kg ha^{-1})	Dry weight of grass weeds (g/m^2)					
		15 DAS			30 DAS		
		Location IV	Location V	Location VI	Location IV	Location V	Location VI
Isoproturon	0.937	10.63^{ef} (112.00)	4.71^{c} (21.20)	7.84^{c} (60.53)	10.86^{e} (117.00)	5.17^{cd} (25.70)	8.08^{c} (64.23)
Mesosulfuron + Iodosulfuron	0.014	10.42^{e} (107.57)	4.62^{c} (20.30)	5.12^{b} (25.20)	10.66^{e} (112.57)	5.08^{cd} (24.80)	5.47^{b} (28.90)
Clodinafop + Metribuzin	0.216	8.09^{b} (64.43)	4.18^{b} (16.50)	5.51^{b} (29.40)	8.21^{b} (66.43)	4.59^{b} (20.10)	5.51^{b} (29.40)
2,4-D amine	0.500	12.07^{h} (144.6)	7.10^{d} (49.40)	8.46^{c} (70.50)	12.27^{h} (149.60)	7.79^{e} (59.70)	8.67^{c} (74.20)
Bispyribac sodium	0.025	9.89^{d} (96.73)	2.76^{ab} (6.60)	4.26^{ab} (17.13)	10.04^{d} (99.73)	3.29^{ab} (9.80)	4.26^{ab} (17.13)
Metribuzin	0.120	9.32^{c} (85.90)	5.13^{c} (25.33)	7.65^{c} (57.57)	9.48^{c} (88.90)	5.68^{d} (31.23)	7.89^{c} (61.27)
Metsulfuron	0.005	11.92^{gh} (141.20)	7.04^{d} (48.50)	8.83^{c} (76.93)	12.30^{gh} (150.20)	7.86^{e} (60.80)	9.03^{c} (80.63)
Carfentrazone-ethyl	0.020	12.07^{h} (144.73)	7.08^{d} (49.10)	8.49^{c} (71.10)	12.44^{h} (153.73)	7.9^{e} (61.40)	8.71^{c} (74.80)
Metsulfuron + Carfentrazone-ethyl	0.025	12.45^{h} (153.90)	6.90^{d} (46.60)	8.76^{c} (75.80)	12.80^{h} (162.90)	7.74^{e} (58.90)	8.97^{c} (79.50)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	11.68^{g} (135.43)	6.91^{d} (46.80)	8.89^{c} (78.03)	12.06^{g} (144.43)	7.75^{e} (59.10)	9.10^{c} (81.73)
Ethoxysulfuron	0.018	10.88^{f} (117.40)	6.57^{d} (42.23)	8.57^{c} (72.50)	11.29^{f} (126.40)	7.45^{e} (54.53)	8.79^{c} (76.20)
Halosulfuron	0.050	12.30^{h} (150.23)	6.63^{d} (43.00)	8.61^{c} (73.10)	12.66^{h} (159.23)	7.50^{e} (55.30)	8.82^{c} (76.80)
Atrazine	1.000	12.19^{h} (147.63)	7.04^{d} (48.50)	8.58^{c} (72.57)	12.56^{h} (156.63)	7.86^{e} (60.80)	8.79^{c} (76.27)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	12.19^{h} (147.60)	6.88^{d} (46.30)	8.43^{c} (70.00)	12.55^{h} (156.60)	7.72^{e} (58.60)	8.64^{c} (73.70)

*Values in the parentheses are original means. Data was subjected to square root transformation √(x+1)

Table 4.2.15: Effect of post-emergence herbicides on periodic dry weight of grass weeds at different locations 45 and 60 DAS in lawn during summer season

Treatments	Dose (kg ha^{-1})	Dry weight of grass weeds (g/m^2)					
		45 DAS			60 DAS		
		Location IV	Location V	Location VI	Location IV	Location V	Location VI
Isoproturon	0.937	11.05^{ef} (121.00)	5.61^{cd} (30.50)	8.37^{c} (69.03)	11.09^{ef} (122.00)	6.25^{cd} (38.10)	8.45^{c} (70.43)
Mesosulfuron + Iodosulfuron	0.014	10.84^{e} (116.57)	5.53^{cd} (29.60)	5.89^{b} (33.70)	10.89^{e} (117.57)	6.18^{cd} (37.20)	6.01^{b} (35.10)
Clodinafop + Metribuzin	0.216	8.45^{b} (70.43)	5.09^{b} (24.90)	5.74^{b} (32.00)	8.51^{b} (71.43)	5.79^{b} (32.50)	5.82^{b} (32.90)
2,4-D amine	0.500	12.43^{h} (153.60)	8.09^{e} (64.50)	8.94^{c} (79.00)	12.47^{h} (154.60)	8.55^{e} (72.10)	9.02^{c} (80.40)
Bispyribac sodium	0.025	10.23^{d} (103.73)	3.95^{b} (14.60)	4.79^{b} (21.93)	10.28^{d} (104.73)	4.82^{b} (22.20)	4.88^{b} (22.83)
Metribuzin	0.120	9.69^{c} (92.90)	6.09^{d} (36.03)	8.19^{c} (66.07)	9.74^{c} (93.90)	6.68^{d} (43.63)	8.27^{c} (67.47)
Metsulfuron	0.005	12.46^{gh} (154.20)	8.16^{e} (65.60)	9.30^{c} (85.43)	12.50^{gh} (155.20)	8.61^{e} (73.20)	9.37^{c} (86.83)
Carfentrazone-ethyl	0.020	12.60^{h} (157.73)	8.20^{e} (66.20)	8.98^{c} (79.60)	12.64^{h} (158.73)	8.65^{e} (73.80)	9.06^{c} (81.00)
Metsulfuron + Carfentrazone-ethyl	0.025	12.96^{h} (166.90)	8.04^{e} (63.70)	9.24^{c} (84.30)	13.00^{h} (167.90)	8.50^{e} (71.30)	9.31^{c} (85.70)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	12.22^{g} (148.43)	8.06^{e} (63.90)	9.36^{c} (86.53)	12.26^{g} (149.43)	8.51^{e} (71.50)	9.43^{c} (87.93)
Ethoxysulfuron	0.018	11.46^{f} (130.40)	7.77^{e} (59.33)	9.06^{c} (81.00)	11.51^{f} (131.40)	8.24^{e} (66.93)	9.13^{c} (82.40)
Halosulfuron	0.050	12.82^{h} (163.23)	7.82^{e} (60.10)	9.09^{c} (81.60)	12.85^{h} (164.23)	8.29^{e} (67.70)	9.17^{c} (83.00)
Atrazine	1.000	12.71^{h} (160.63)	8.16^{e} (65.60)	9.06^{c} (81.07)	12.75^{h} (161.63)	8.61^{e} (73.20)	9.14^{c} (82.47)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	3.24^{a} (9.50)	4.03^{a} (15.30)
Un-weeded (control)	-	12.71^{h} (160.60)	8.02^{e} (63.40)	8.92^{c} (78.50)	12.83^{h} (163.60)	8.49^{e} (71.00)	9.05^{c} (80.90)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.2.12: Dry weight of grass weeds after spray of post-emergence herbicides in lawn during summer season

Weed flora differs at different locations. The dry weight of grass weeds when recorded after 15 and 30 days of different herbicides application at different locations as presented in Table 4.2.14 revealed that hand weeding provided significantly lower dry weight as compared with other weed control treatments and weedy check at all locations. Second best treatment at Location IV was clodinafop + metribuzin @ 0.216 kg ha^{-1} which helped to reduce the dry weight of grass weeds and significantly better than other herbicides. The lower weed density of grass weed viz. *Digitaria sanguinalis* (Table 4.2.1) and *Dactyloctenium aegyptium* (Table 4.2.5) at Location IV was recorded at 15 and 30 DAS. The dry weight of grass weeds at location V as influenced by bispyribac sodium @ 0.025 kg ha^{-1} proved to be second best treatment which was at par with hand weeding and clodinafop + metribuzin @ 0.216 kg ha^{-1}. The density of *Dicanthium annulatum* (Table 4.2.3.) was lower as compared with remaining herbicides. At Location V, *Dicanthium annulatum* and *Paspalum dilatatum* were observed (Table 4.2.1 and Table 4.2.6). Bispyribac sodium @ 0.025 kg ha^{-1} effectively reduced the dry weight of *Dicanthium annulatum* and was at par with hand weeding, clodinafop + metribuzin @ 0.216 kg ha^{-1} and mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1} at 15 and 30 DAS, However, *Paspalum dilatatum* was effectively controlled by mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1} as compared with other herbicides.

The dry weight of grass weeds when recorded after 45 and 60 days of different post-emergence herbicides application at different locations as presented in Table 4.2.15 revealed that two hand weedings provided significantly lower values of dry weight as compared with other weed control treatments and weedy check at all locations. Second best treatment at 45 and 60 DAS was clodinafop + metribuzin @ 0.216 kg ha^{-1} which helped to reduce the dry weight of grass weeds at all the locations. Clodinafop + metribuzin @ 0.216 kg ha^{-1} was at par with bispyribac sodium @ 0.025 kg ha^{-1} at Location V. At Location VI clodinafop + metribuzin @ 0.216 kg ha^{-1} was at par with bispyribac sodium @ 0.025 kg ha^{-1} and mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1} at 45 and 60 DAS in lawn during summer season.

Table 4.2.16: Effect of post-emergence herbicides on periodic dry weight of broadleaf weeds at different locations 15 and 30 DAS in lawn during summer season

Treatments	Dose (kg ha^{-1})	Dry weight of broadleaf weeds (g/m^2)					
		15 DAS			30 DAS		
		Location IV	Location V	Location VI	Location IV	Location V	Location VI
Isoproturon	0.937	6.03^{d} (35.37)	3.91^{de} (14.3)	4.02^{de} (15.2)	6.95^{c} (47.37)	4.30^{de} (17.5)	4.66^{d} (20.7)
Mesosulfuron + Iodosulfuron	0.014	8.34^{e} (68.53)	4.05^{e} (15.40)	4.36^{e} (18.00)	9.03^{d} (80.53)	4.43^{e} (18.6)	4.95^{d} (23.5)
Clodinafop + Metribuzin	0.216	8.50^{e} (71.30)	2.85^{bc} (7.10)	3.08^{bc} (8.47)	9.18^{d} (83.30)	3.36^{bc} (10.30)	3.60^{bc} (11.97)
2,4-D amine	0.500	8.28^{e} (67.63)	3.91^{de} (14.30)	3.26^{cd} (9.60)	8.98^{d} (79.63)	4.30^{de} (17.50)	3.78^{c} (13.27)
Bispyribac sodium	0.025	8.30^{e} (67.93)	3.95^{e} (14.60)	4.16^{e} (16.33)	9.00^{d} (79.93)	4.34^{e} (17.80)	4.78^{d} (21.83)
Metribuzin	0.120	8.20^{e} (66.27)	3.99^{e} (14.90)	3.14^{bc} (8.87)	8.90^{d} (78.27)	4.37^{e} (18.10)	3.74^{bc} (12.97)
Metsulfuron	0.005	3.80^{b} (13.47)	3.75^{c} (13.10)	2.86^{b} (7.17)	4.47^{b} (18.97)	4.16^{cd} (16.30)	3.33^{b} (10.07)
Carfentrazone-ethyl	0.020	4.80^{c} (22.00)	3.79^{c} (13.40)	2.65^{b} (6.03)	5.34^{c} (27.50)	4.20^{cd} (16.60)	3.15^{b} (8.93)
Metsulfuron + Carfentrazone-ethyl	0.025	1.00^{a} (0)	2.66^{bc} (6.10)	1.00^{a} (0)	1.00^{a} (0)	3.21^{bc} (9.30)	1.00^{a} (0)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	3.36^{b} (10.30)	3.18^{c} (9.10)	3.09^{bc} (8.57)	4.39^{b} (18.30)	3.65^{cd} (12.30)	3.64^{bc} (12.27)
Ethoxysulfuron	0.018	8.13^{e} (65.13)	4.12^{e} (16.00)	4.29^{e} (17.43)	8.84^{d} (77.13)	4.49^{e} (19.20)	4.89^{d} (22.93)
Halosulfuron	0.050	8.58^{e} (72.60)	3.91^{de} (14.30)	4.02^{de} (15.20)	9.25^{d} (84.60)	4.30^{de} (17.50)	4.66^{d} (20.70)
Atrazine	1.000	8.45^{e} (70.37)	2.55^{bc} (5.50)	3.71^{cde} (12.80)	9.13^{d} (82.37)	3.11^{bc} (8.70)	4.39^{cd} (18.30)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	8.45^{e} (70.47)	4.09^{e} (15.70)	4.36^{e} (18.00)	9.14^{d} (82.47)	4.46^{e} (18.90)	4.95^{d} (23.50)

*Values in the parentheses are original means. Data was subjected to square root transformation √(x+1)

4.2.13: Dry weight of broadleaf weeds after spray of different herbicides in lawn

Weed flora differs at different locations. The dry weight of broadleaf weeds at 15 and 30 DAS revealed that hand weeding provided significantly lower dry weight as compared with herbicides and weedy check at all the locations (Table 4.2.16.). Two hand weedings was at par with metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} at Location IV and Location V. Second best treatments at Location IV were metsulfuron @ 0.005 kg ha^{-1} and metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1} which helped to reduce the dry weight of broadleaf weeds and significantly better than other herbicides. The lower density of broadleaf weed viz. *Boerhavia diffusa* (Table 4.2.7.) and *Alysicarpus vaginalis* (Table 4.2.8.) at Location IV was recorded at 15 and 30 DAS. The dry weight at location V as influenced by clodinafop + metribuzin @ 0.216 kg ha^{-1}, metsulfuron + carfentrazone-ethyl @ 0.025 kg atrazine @ 1.0 kg ha^{-1} proved to be second best treatment which was at par with metsulfuron @ 0.005 kg ha^{-1}, carfentrazone-ethyl @ 0.020 kg ha^{-1} and metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1} at 15 and 30 DAS. At Location V, the density of *Evolvulus nummularius* (Table 4.2.9.) was lower as compared with remaining herbicides. At Location VI, *Desmodium triflorum* was observed (Table 4.2.10.). Clodinafop + metribuzin @ 0.216 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1}, carfentrazone-ethyl @ 0.020 kg ha^{-1} and metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1} effectively reduced the dry weight of this weed. Clodinafop + metribuzin @ 0.216 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1} were at par with 2,4-D amine @ 0.5 kg ha^{-1} and atrazine @ 1.0 kg ha^{-1} at 15 and 30 DAS.

The dry weight of broadleaf weeds at 45 DAS revealed that two hand weedings and metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} provided significantly lower dry weight as compared with other herbicides and weedy check at Location IV and Location V whereas at location VI two hand weedings provided complete control as compare with other treatments (Table 4.2.17.). Second best treatments at 45 DAS were metsulfuron @ 0.005 kg ha^{-1}, carfentrazone-ethyl @ 0.020 kg ha^{-1} and metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1} which helped to reduce the dry weight of broadleaf weeds and significantly better than other herbicides at Location IV. At Location V, clodinafop + metribuzin @ 0.216 kg ha^{-1}, metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and atrazine @ 1.0 kg ha^{-1} proved to second best treatment at 45 DAS. At Location VI, clodinafop + metribuzin @ 0.216 kg ha^{-1}, 2,4-D amine @ 0.5 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1}, carfentrazone-ethyl @ 0.020 kg ha^{-1} and metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1} effectively reduced the dry weight broadleaf weeds. Clodinafop + metribuzin @ 0.216 kg ha^{-1}, 2,4-D amine @ 0.5kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1} were at par with atrazine @ 1.0 kg ha^{-1} at 45. At 60 DAS, two hand weedings and metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} provided significantly lower values of dry weight followed by metsulfuron @ 0.005 kg ha^{-1}, carfentrazone-ethyl @ 0.020 kg ha^{-1} and metsulfuron-methyl + chlorimuron-ethyl @ 0.004 kg ha^{-1} at Location IV. At Location V, lower dry weight was recorded in two hand weedings followed by clodinafop + metribuzin @ 0.216

kg ha^{-1}, metsulfuron + carfentrazone-ethyl @ 0.025 kg atrazine @ 1.0 kg ha^{-1}. At Location VI, metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and two hand weedings provided better control of broadleaf weeds than other herbicides. Second best herbicides were metsulfuron @ 0.005 kg ha^{-1}, carfentrazone-ethyl @ 0.020 kg ha^{-1}.

Table 4.2.17: Effect of post-emergence herbicides on periodic dry weight of broadleaf weeds at different locations 45 and 60 DAS in lawn during summer season

Treatments	Dose (kg ha^{-1})	Dry weight of broadleaf weeds (g/m^2)					
		45 DAS			60 DAS		
		Location IV	Location V	Location VI	Location IV	Location V	Location VI
Isoproturon	0.937	7.41^{c} (53.97)	4.59^{de} (20.10)	5.03^{d} (24.30)	7.62^{c} (57.07)	4.59^{de} (20.10)	5.30^{de} (27.10)
Mesosulfuron + Iodosulfuron	0.014	9.39^{d} (87.13)	4.71^{e} (21.20)	5.30^{d} (27.10)	9.55^{d} (90.23)	4.71^{e} (21.20)	5.56^{de} (29.90)
Clodinafop + Metribuzin	0.216	9.53^{d} (89.90)	3.73^{c} (12.90)	4.07^{bc} (15.57)	9.70^{d} (93.00)	3.73^{c} (12.90)	4.40^{c} (18.37)
2,4-D amine	0.500	9.34^{d} (86.23)	4.59^{de} (20.10)	4.23^{bc} (16.87)	9.50^{d} (89.33)	4.59^{de} (20.10)	4.55^{c} (19.67)
Bispyribac sodium	0.025	9.36^{d} (86.53)	4.63^{e} (20.40)	5.14^{d} (25.43)	9.52^{d} (89.63)	4.63^{e} (20.40)	5.41^{de} (28.23)
Metribuzin	0.120	9.27^{d} (84.87)	4.66^{e} (20.70)	4.19^{bc} (16.57)	9.43^{d} (87.97)	4.66^{e} (20.70)	4.51^{c} (19.37)
Metsulfuron	0.005	5.15^{b} (25.57)	4.46^{d} (18.90)	3.83^{b} (13.67)	5.45^{b} (28.67)	4.46^{d} (18.90)	4.18^{b} (16.47)
Carfentrazone-ethyl	0.020	5.92^{b} (34.1)	4.49^{d} (19.20)	3.68^{b} (12.53)	6.18^{b} (37.20)	4.49^{d} (19.20)	4.04^{b} (15.33)
Metsulfuron + Carfentrazone-ethyl	0.025	1.00^{a} (0)	3.59^{c} (11.90)	1.00^{a} (0)	1.00^{a} (0)	3.59^{c} (11.90)	2.85^{a} (7.10)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	5.09^{b} (24.90)	3.99^{d} (14.90)	4.11^{bc} (15.87)	5.39^{b} (28.00)	3.99^{d} (14.90)	4.44^{c} (18.67)
Ethoxysulfuron	0.018	9.20^{d} (83.73)	4.77^{e} (21.80)	5.25^{d} (26.53)	9.37^{d} (86.83)	4.77^{e} (21.80)	5.51^{de} (29.33)
Halosulfuron	0.050	9.60^{d} (91.20)	4.59^{de} (20.10)	5.03^{d} (24.30)	9.76^{d} (94.30)	4.59^{de} (20.10)	5.30^{de} (27.10)
Atrazine	1.000	9.49^{d} (88.97)	3.51^{c} (11.30)	4.79^{cd} (21.90)	9.65^{d} (92.07)	3.51^{c} (11.30)	5.07^{cd} (24.70)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	2.85^{a} (7.10)	2.91^{a} (7.50)
Un-weeded (control)	-	9.49^{d} (89.07)	4.74^{e} (21.50)	5.30^{d} (27.10)	9.65^{d} (92.17)	4.74^{e} (21.50)	5.67^{e} (31.10)

*Values in the parentheses are original means. Data was subjected to square root transformation √(x+1)

Table 4.2.18: Effect of post-emergence herbicides on periodic dry weight of sedge weeds at Location IV in lawn during summer season

Treatments	Dose (kg ha^{-1})	Dry weight of sedges (g m^{-2})			
		15 DAS	30 DAS	45 DAS	60 DAS
Isoproturon	0.937	3.89^{b} (14.1)	4.21^{c} (16.7)	4.48^{c} (19.1)	4.69^{c} (21)
Mesosulfuron + Iodosulfuron	0.014	3.7^{b} (12.7)	4.04^{c} (15.3)	4.32^{c} (17.7)	4.54^{c} (19.6)
Clodinafop + Metribuzin	0.216	3.78^{b} (13.3)	4.11^{c} (15.9)	4.39^{c} (18.3)	4.6^{c} (20.2)
2,4-D amine	0.500	2.32^{a} (4.4)	2.83^{b} (7.0)	3.22^{b} (9.4)	3.51^{b} (11.3)
Bispyribac sodium	0.025	3.89^{b} (14.1)	4.21^{c} (16.7)	4.48^{c} (19.1)	4.69^{c} (21)
Metribuzin	0.120	3.89^{b} (14.1)	4.21^{c} (16.7)	4.48^{c} (19.1)	4.69^{c} (21)
Metsulfuron	0.005	3.85^{b} (13.8)	4.17^{c} (16.4)	4.45^{c} (18.8)	4.66^{c} (20.7)
Carfentrazone-ethyl	0.020	3.7^{b} (12.7)	4.04^{c} (15.3)	4.32^{c} (17.7)	4.54^{c} (19.6)
Metsulfuron + Carfentrazone-ethyl	0.025	3.66^{b} (12.4)	4.00^{c} (15)	4.32^{c} (17.7)	4.51^{c} (19.3)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	3.66^{b} (12.4)	4.04^{c} (15.3)	4.29^{c} (17.4)	4.51^{c} (19.3)
Ethoxysulfuron	0.018	1.00^{a} (0)	1.00^{a} (0)	2.24^{ab} (4)	2.63^{ab} (5.9)
Halosulfuron	0.050	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	2.21^{a} (3.9)
Atrazine	1.000	3.66^{b} (12.4)	4.00^{c} (15)	4.29^{c} (17.4)	4.51^{c} (19.3)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	2.35^{ab} (4.5)	2.72^{ab} (6.4)
Un-weeded (control)	-	3.92^{b} (14.4)	4.24^{c} (17)	4.52^{c} (19.4)	4.72^{c} (21.3)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.2.14: Dry weight of sedge weeds after spray of herbicides during summer season

The dry weight of sedges recorded after 15, 30, 45 and 60 days of different herbicides application at Location IV are presented in Table 4.2.18. The lowest dry weight was recorded in ethoxysulfuron @ 0.018 kg ha^{-1}, halosulfuron @ 0.050 kg ha^{-1}, 2,4-D amine @ 0.5 kg ha^{-1} and hand weeding which was significantly lower than all other herbicides and unweeded check when observed at 15 DAS. These herbicides controlled this weed upto 30 DAS except 2,4-D amine @ 0.5 kg ha^{-1}. Halosulfuron @ 0.050 kg ha^{-1} provided complete control upto 45 DAS and showed resprouting when observed at 60 DAS whereas re-sprouting was recorded in ethoxysulfuron @ 0.018 kg ha^{-1} and two hand weedings when observed at 45 DAS. The weeds belonging to sedges did not appear at other locations.

Table 4.2.19: Total dry weight of weeds before the spray of post-emergence herbicides at different locations in lawn during summer season

Treatments	Total dry weight (g m^{-2}) before spray		
	Location IV	Location V	Location VI
Isoproturon	177.40	38.07	66.67
Mesosulfuron + Iodosulfuron	174.00	38.30	72.47
Clodinafop + Metribuzin	169.00	38.90	66.67
2,4-D amine	168.80	39.00	64.97
Bispyribac sodium	162.80	41.20	68.87
Metribuzin	159.17	36.30	70.83
Metsulfuron	167.10	39.20	68.87
Carfentrazone-ethyl	172.60	40.10	61.93
Metsulfuron + Carfentrazone-ethyl	180.30	37.90	68.60
Metsulfuron-methyl + Chlorimuron-ethyl	156.60	36.90	71.10
Ethoxysulfuron	162.50	38.60	69.43
Halosulfuron	179.40	38.60	64.43
Atrazine	173.70	39.00	64.17
Two hand weedings (15 days interval)	166.80	36.23	70.27
Un-weeded (control)	175.70	37.30	63.63

4.2.15: Total dry weight of weeds before the spray of herbicides during summer season

The total dry weight of weeds before the application of different herbicides at different locations are presented in Table 4.3.15. The total dry weight ranged between 156.60 g to 180.30 g m^{-2} at Location IV, whereas this range was 36.23 g to 41.20 g and 61.93 g to 72.47 g m^{-2}, respectively at Location V and Location VI. The difference in the total dry weight of weeds was non-significant as the weight was recorded before the spray of different post-emergence herbicides in lawn during the summer season.

Table 4.2.20: Effect of post-emergence herbicides on periodic total dry weight of weeds at different locations 15 and 30 DAS in lawn

Treatments	Dose (kg ha^{-1})	Total dry weight of weeds (g m^{-2})					
		15 DAS			30 DAS		
		Location IV	Location V	Location VI	Location IV	Location V	Location VI
Isoproturon	0.937	12.75^{bc} (161.50)	6.05^{cd} (35.57)	8.76^{d} (75.77)	13.49^{bcd} (181.1)	6.65^{c} (43.27)	9.27^{d} (84.97)
Mesosulfuron + Iodosulfuron	0.014	13.78^{d} (188.8)	6.07^{cd} (35.80)	6.65^{bc} (43.17)	14.47^{e} (208.40)	6.67^{c} (43.50)	7.31^{bc} (52.37)
Clodinafop + Metribuzin	0.216	12.25^{b} (149.00)	4.96^{bc} (23.60)	6.23^{bc} (37.87)	12.91^{b} (165.6)	5.60^{b} (30.40)	6.51^{b} (41.37)
2,4-D amine	0.500	14.75^{e} (216.7)	8.04^{f} (63.70)	9.00^{d} (80.07)	15.40^{f} (236.30)	8.84^{d} (77.20)	9.41^{d} (87.47)
Bispyribac sodium	0.025	13.41^{cd} (178.80)	4.71^{b} (21.20)	5.87^{b} (33.47)	14.05^{cde} (196.40)	5.35^{b} (27.60)	6.32^{b} (38.97)
Metribuzin	0.120	12.93^{bcd} (166.20)	6.42^{cde} (40.23)	8.21^{cd} (66.43)	13.59^{bcd} (183.80)	7.09^{c} (49.33)	8.67^{cd} (74.23)
Metsulfuron	0.005	13.02^{bcd} (168.50)	7.91^{f} (61.60)	9.22^{d} (84.07)	13.66^{bcd} (185.60)	8.84^{d} (77.10)	9.57^{d} (90.67)
Carfentrazone-ethyl	0.020	13.44^{cd} (179.50)	7.97^{f} (62.50)	8.84^{d} (77.13)	14.06^{cde} (196.60)	8.89^{d} (78.00)	9.20^{d} (83.73)
Metsulfuron + Carfentrazone-ethyl	0.025	12.94^{bcd} (166.33)	7.33^{def} (52.70)	8.76^{d} (75.80)	13.38^{bc} (177.93)	8.32^{d} (68.20)	8.97^{cd} (79.50)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	13.04^{cd} (169.07)	7.54^{ef} (55.80)	9.36^{d} (86.60)	13.77^{cde} (188.67)	8.50^{d} (71.30)	9.75^{d} (94.00)
Ethoxysulfuron	0.018	13.55^{cd} (182.57)	7.69^{f} (58.20)	9.54^{d} (89.93)	14.30^{de} (203.57)	8.64^{d} (73.71)	10.01^{d} (99.13)
Halosulfuron	0.050	14.96^{e} (222.80)	7.64^{ef} (57.30)	9.45^{d} (88.33)	15.65^{f} (243.80)	8.59^{d} (72.82)	9.93^{d} (97.53)
Atrazine	1.000	15.21^{e} (230.40)	7.42^{ef} (54.00)	9.29^{d} (85.37)	15.97^{f} (254.00)	8.40^{d} (69.50)	9.78^{d} (94.57)
Two hand weedings (15 days interval)	-	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)	1.00^{a} (0)
Un-weeded (control)	-	15.28^{e} (232.40)	7.94^{f} (62.00)	9.44^{d} (88.03)	16.03^{f} (256.00)	8.86^{d} (77.51)	9.91^{d} (97.23)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

Table 4.2.21: Effect of post-emergence herbicides on periodic total dry weight of weeds at different locations 45 and 60 DAS in lawn

Treatments	Dose (kg ha^{-1})	Total dry weight of weeds (g m^{-2}) at					
		45 DAS			60 DAS		
		Location IV	Location V	Location VI	Location IV	Location V	Location VI
Isoproturon	0.937	13.97^{bcd} (194.1)	7.19^{c} (50.67)	9.71^{d} (93.37)	14.18^{bcd} (200.1)	7.70^{c} (58.27)	9.93^{d} (97.57)
Mesosulfuron + Iodosulfuron	0.014	14.91^{f} (221.4)	7.20^{bc} (50.91)	7.86^{bc} (60.77)	15.11^{f} (227.4)	7.71^{bc} (58.50)	8.12^{bc} (64.97)
Clodinafop + Metribuzin	0.216	13.4^{b} (178.6)	6.23^{b} (37.81)	6.97^{b} (47.57)	13.62^{b} (184.6)	6.81^{b} (45.40)	7.23^{b} (51.27)
2,4-D amine	0.5	15.82^{g} (249.3)	9.25^{d} (84.62)	9.84^{d} (95.87)	16.01^{f} (255.3)	9.65^{d} (92.20)	10.05^{d} (100.07)
Bispyribac sodium	0.025	14.51^{def} (209.4)	6.00^{b} (35.00)	6.95^{b} (47.37)	14.71^{def} (215.4)	6.60^{b} (42.60)	7.22^{b} (51.07)
Metribuzin	0.120	14.06^{bcde} (196.8)	7.60^{c} (56.73)	9.14^{cd} (82.63)	14.28^{bcde} (202.8)	8.08^{c} (64.33)	9.37^{cd} (86.83)
Metsulfuron	0.005	14.13^{bcde} (198.6)	9.25^{d} (84.55)	10.00^{d} (99.07)	14.34^{bcde} (204.6)	9.65^{d} (92.11)	10.21^{d} (103.27)
Carfentrazone-ethyl	0.020	14.51^{def} (209.6)	9.30^{d} (85.45)	9.65^{d} (92.13)	14.72^{def} (215.6)	9.70^{d} (93.00)	9.87^{d} (96.33)
Metsulfuron + Carfentrazone-ethyl	0.025	13.61^{bc} (184.33)	8.75^{d} (75.60)	9.24^{cd} (84.3)	13.72^{bc} (187.23)	9.18^{d} (83.22)	9.69^{cd} (92.80)
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	14.24^{cdef} (201.67)	8.93^{d} (78.71)	10.17^{d} (102.4)	14.45^{cdef} (207.67)	9.34^{d} (86.30)	10.37^{d} (106.60)
Ethoxysulfuron	0.018	14.8^{ef} (218.17)	9.06^{d} (81.10)	10.42^{d} (107.53)	15.01^{ef} (224.17)	9.47^{d} (88.75)	10.62^{d} (111.73)
Halosulfuron	0.050	15.98^{g} (254.4)	9.01^{d} (80.21)	10.34^{d} (105.93)	16.23^{f} (262.4)	9.42^{d} (87.82)	10.54^{d} (110.13)
Atrazine	1.0	16.37^{g} (267)	8.83^{d} (76.90)	10.20^{d} (102.97)	16.55^{f} (273)	9.25^{d} (84.54)	10.40^{d} (107.17)
Two hand weedings (15 days interval)	-	2.35^{a} (4.5)	1.00^{a} (0)	1.00^{a} (0)	2.72^{a} (6.4)	4.20^{a} (16.60)	4.88^{a} (22.80)
Un-weeded (control)	-	16.43^{g} (269)	9.27^{d} (84.90)	10.33^{d} (105.63)	16.67^{f} (277)	9.67^{d} (92.50)	10.63^{d} (112.03)

*Values in the parentheses are original means. Data was subjected to square root transformation $\sqrt{(x+1)}$

4.2.16: Total dry weight of weeds after spray different herbicides

Weed flora differs at different locations. The total dry weight of weeds when recorded after 15 and 30 days of different herbicides application at different locations as presented in Table 4.3.10 revealed that hand weeding treatment provided significantly lower dry weight as compared with other weed control treatments and weedy check at all locations. Second best treatment at Location IV was clodinafop + metribuzin @ 0.216 kg ha^{-1} which helped to reduce the total dry weight of weeds and was at par with isoproturon @ 0.937 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1}, metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} at 15 and 30 DAS. The total dry weight of weeds at Location V as influenced by bispyribac sodium @ 0.025 kg ha^{-1} proved to be second best treatment which was at par with clodinafop + metribuzin @ 0.216 kg ha^{-1}. At Location VI, bispyribac sodium @ 0.025 kg ha^{-1} effectively reduced the total dry weight of weeds and was at par with mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1} and clodinafop + metribuzin @ 0.216 kg ha^{-1} at 15 and 30 DAS.

The total dry weight weeds when recorded after 45 and 60 days of different herbicides application at different locations as presented in Table 4.3.11 revealed that hand weeding treatment provided significantly lower values of dry weight as compared with other weed control treatments and weedy check at all locations. Second best treatment at 45 and 60 DAS at Location IV was clodinafop + metribuzin @ 0.216 kg ha^{-1} which helped to reduce the total dry weight of weeds and was at par with isoproturon @ 0.937 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, metsulfuron @ 0.005 kg ha^{-1}, metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1}. At Location V and Location VI, bispyribac sodium @ 0.025 kg ha^{-1} helped to reduce the total dry weight of weeds and was at par with clodinafop + metribuzin @ 0.216 kg ha^{-1} and mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1}.

Table 4.2.22: Weed control efficiency of different post-emergence herbicides at 15 and 30 DAS in lawn during summer season

Treatments	Dose (kg ha^{-1})	Weed control efficiency (%)							
		15 DAS				30 DAS			
		Location IV	Location V	Location VI	Mean	Location IV	Location V	Location VI	Mean
Isoproturon	0.937	30.5	42.6	13.9	29.0	29.3	44.2	12.6	28.7
Mesosulfuron + Iodosulfuron	0.014	18.8	42.3	51.0	37.4	18.6	43.9	46.1	36.2
Clodinafop + Metribuzin	0.216	35.9	61.9	57.0	51.6	35.3	60.8	57.5	51.2
2,4-D amine	0.500	6.8	0.4	9.0	5.4	7.7	0.4	10.0	6.0
Bispyribac sodium	0.025	23.1	65.8	62.0	50.3	23.3	64.4	59.9	49.2
Metribuzin	0.120	28.5	35.1	24.5	29.4	28.2	36.3	23.7	29.4
Metsulfuron	0.005	27.5	0.6	4.5	10.9	27.5	0.5	6.8	11.6
Carfentrazone-ethyl	0.020	22.8	0.3	12.4	11.8	23.2	0.3	13.9	12.5
Metsulfuron + Carfentrazone-ethyl	0.025	28.4	15.0	13.9	19.1	30.5	12.0	18.2	20.2
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	27.3	10.0	1.6	13.0	26.3	8.0	3.3	12.5
Ethoxysulfuron	0.018	21.4	6.1	0.0	9.2	20.5	4.9	0.0	8.5
Halosulfuron	0.050	4.1	7.6	0.0	3.9	4.8	6.1	0.0	3.6
Atrazine	1.000	0.9	12.9	3.0	5.6	0.8	10.3	2.7	4.6
Two hand weedings (15 days interval)	-	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Un-weeded (control)	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4.2.23: Weed control efficiency of different post-emergence herbicides at 45 and 60 DAS in lawn during summer season

Treatments	Dose (kg ha^{-1})	Weed control efficiency (%)							
		45 DAS				60 DAS			
		Location IV	Location V	Location VI	Mean	Location IV	Location V	Location VI	Mean
Isoproturon	0.937	27.8	40.3	11.6	26.6	27.8	37.0	12.9	25.9
Mesosulfuron + Iodosulfuron	0.014	17.7	40.0	42.5	33.4	17.9	36.8	42.0	32.2
Clodinafop + Metribuzin	0.216	33.6	55.5	55.0	48.0	33.4	50.9	54.2	46.2
2,4-D amine	0.500	7.3	0.4	9.2	5.6	7.8	0.3	10.7	6.3
Bispyribac sodium	0.025	22.2	58.8	55.2	45.4	22.2	53.9	54.4	43.5
Metribuzin	0.120	26.8	33.2	21.8	27.3	26.8	30.5	22.5	26.6
Metsulfuron	0.005	26.2	0.5	6.2	11.0	26.1	0.4	7.8	11.4
Carfentrazone-ethyl	0.020	22.1	0.2	12.8	11.7	22.2	0.2	14.0	12.1
Metsulfuron + Carfentrazone-ethyl	0.025	31.5	11.0	20.2	20.9	32.4	10.1	17.2	19.9
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	25.0	7.3	3.1	11.8	25	6.7	4.8	12.2
Ethoxysulfuron	0.018	18.9	4.5	0.0	7.8	19.1	4.1	0.3	7.8
Halosulfuron	0.050	5.4	5.5	0.0	3.6	5.3	5.1	1.7	4.0
Atrazine	1.000	0.7	9.4	2.5	4.2	1.4	8.6	4.3	4.8
Two hand weedings (15 days interval)	-	98.3	100.0	100.0	99.4	97.7	82.1	79.6	86.5
Un-weeded (control)	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4.2.17: Weed control efficiency of different post-emergence herbicicdes

Weed control efficiency was calculated at 15, 30, 45 and 60 DAS and presented in Table 4.2.22 and Table 4.2.23. Among the herbicide treatments at 15 DAS, hand weeding resulted in obtaining the highest (100%) mean weed control efficiency followed by clodinafop + metribuzin @ 0.216 kg ha^{-1} and bispyribac sodium @ 0.025 kg ha^{-1} as 51.6 and 50.3 per cent, respectively at the different locations. When observed at 30 DAS, the highest (100%) WCE was calculated in two hand weedings, followed by clodinafop + metribuzin @ 0.216 kg ha^{-1} (51.2 %) and bispyribac sodium @ 0.025 kg ha^{-1} (49.2%). The weed control efficiency at 45 DAS in two hand weedings was 99.4 per cent and that in clodinafop + metribuzin @ 0.216 kg ha^{-1} was 48.0 per cent. These values were slightly lower as 46.2 and 86.5 per cent respectively, in clodinafop + metribuzin @ 0.216 kg ha^{-1} and hand weeding treatment at 60 DAS.

Table 4.2.24: Sward height of turfgrass before mowing at 60 DAS during summer season

Treatments	**Dose (kg ha^{-1})**	**Sward height (cm)**		
		Location IV	Location V	Location VI
Isoproturon	0.937	20.1^{c}	18.2^{bc}	18.6^{cd}
Mesosulfuron + Iodosulfuron	0.014	17.1^{e}	18.5^{bc}	26.1^{ab}
Clodinafop + Metribuzin	0.216	21.5^{b}	20.8^{abc}	26.1^{ab}
2,4-D amine	0.500	18.1^{e}	17.0^{c}	17.6^{de}
Bispyribac sodium	0.025	19.1^{d}	22.7^{ab}	27.1^{ab}
Metribuzin	0.120	19.6^{c}	17.7^{c}	19.1^{c}
Metsulfuron	0.005	19.1^{d}	17.2^{c}	18.6^{cd}
Carfentrazone-ethyl	0.020	18.6^{e}	17.8^{c}	19.6^{c}
Metsulfuron + Carfentrazone-ethyl	0.025	21.1^{b}	18.2^{bc}	21.1^{b}
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	18.6^{e}	17.2^{c}	18.1^{cd}
Ethoxysulfuron	0.018	18.1^{e}	16.7^{d}	17.6^{de}
Halosulfuron	0.050	18.4^{e}	17.4^{c}	17.1^{de}
Atrazine	1.000	18.1^{e}	17.8^{c}	17.6^{de}
Two hand weedings (15 days interval)	-	24.1^{a}	24.7^{a}	29.1^{a}
Un-weeded (control)	-	15.1^{f}	14.7^{d}	15.1^{e}

4.2.18: Sward height of turfgrass before mowing

Sward height of turfgrass was measured by scale at 60 DAS before mowing. The values as presented in Table 4.2.24 revealed that two hand weeding treatment showed significantly more sward height (24.1, 24.7 and 29.1 cm) as compared with weedy check and other herbicicde treatments at location IV, location V and location VI, respectively. Second best treatments were metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and clodinafop + metribuzin @ 0.216 kg ha^{-1} at Location IV, clodinafop + metribuzin @ 0.216 kg and bispyribac sodium @ 0.025 kg ha^{-1} at Location V and mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1}, clodinafop + metribuzin @ 0.216 kg ha^{-1} and bispyribac sodium @ 0.025 kg ha^{-1} at Location

VI. The sward height varied as per the presence of different weed flora as presented in Tables (Table 4.2.1 to Table 4.2.11.).

Table 4.2.25: Turfgrass colour before mowing at 60 DAS during summer season

Treatments	Dose (kg ha^{-1})	Turfgrass colour (1-9 scale)			
		Location IV	Location V	Location VI	Mean
Isoproturon	0.937	8	8	8	8
Mesosulfuron + Iodosulfuron	0.014	8	8	8	8
Clodinafop + Metribuzin	0.216	8	8	8	8
2,4-D amine	0.500	8	8	8	8
Bispyribac sodium	0.025	8	8	8	8
Metribuzin	0.120	8	8	8	8
Metsulfuron	0.005	8	8	8	8
Carfentrazone-ethyl	0.020	8	8	8	8
Metsulfuron + Carfentrazone-ethyl	0.025	8	8	8	8
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	8	8	8	8
Ethoxysulfuron	0.018	8	8	8	8
Halosulfuron	0.050	8	8	8	8
Atrazine	1.000	8	8	8	8
Two hand weedings (15 days interval)	-	8	8	8	8
Un-weeded (control)	-	8	8	8	8

4.2.19: Turfgrass colour before mowing at 60 DAS

Turfgrass colour was recorded as 1-9 scale (Voss, 2002) at 60 DAS before mowing and are presented in Table 4.2.25. The difference in the turfgrass colour was non-significant as the rating was recorded before mowing at 60 DAS during summer season.

4.2.20: Fresh weight of turfgrass clippings after mowing at different locations

The fresh weight of turfgrass clippings was recorded at 60 DAS after mowing and presented in Table 4.7.26. Among the herbicide treatments, two hand weedings resulted in obtaining the maximum fresh weight and significantly more as compared with other herbicides followed by clodinafop + metribuzin @ 0.216 kg ha^{-1} at Location IV, bispyribac sodium @ 0.025 kg ha^{-1} at Location V, mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1} and bispyribac sodium @ 0.025 kg ha^{-1} at Location VI. Minimum fresh weight of turfgrass was recorded in un-weeded control at all the locations. The fresh weight of turfgrass clippings varied as per the weed density as presented in Tables (Table 4.2.1. to Table 4.2.11.) and total dry weight of weeds (Table 4.2.21.) The maximum fresh weight of clippings was exhibited by treatments having less weeds and more weed control efficiency (Table 4.2.23.).

Table 4.2.26: Fresh weight of turfgrass clippings after mowing at 60 DAS during summer season at different locations

Treatments	Dose (kg ha^{-1})	Fresh weight of clippings (g m^{-2})		
		Location IV	Location V	Location VI
Isoproturon	0.937	94.12^{bc}	75.14^{c}	85.12^{cd}
Mesosulfuron + Iodosulfuron	0.014	89.15^{cde}	73.12^{cd}	95.12^{ab}
Clodinafop + Metribuzin	0.216	98.12^{ab}	81.15^{b}	91.13^{b}
2,4-D amine	0.500	85.17^{de}	69.13^{e}	75.12^{e}
Bispyribac sodium	0.025	90.16^{cde}	87.13^{a}	95.12^{ab}
Metribuzin	0.120	95.12^{bc}	73.14^{cd}	87.13^{cd}
Metsulfuron	0.005	91.15^{bcd}	69.12^{e}	85.13^{cd}
Carfentrazone-ethyl	0.020	90.14^{cde}	68.15^{e}	86.11^{cd}
Metsulfuron + Carfentrazone-ethyl	0.025	94.17^{bc}	70.13^{de}	90.13^{bc}
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	91.16^{bcd}	69.13^{e}	84.13^{cd}
Ethoxysulfuron	0.018	87.15^{de}	68.14^{e}	81.12^{de}
Halosulfuron	0.050	87.15^{de}	69.12^{e}	80.12^{de}
Atrazine	1.000	85.12^{de}	69.65^{de}	80.62^{de}
Two hand weedings (15 days interval)	-	105.13^{a}	85.13^{a}	101.13^{a}
Un-weeded (control)	-	79.14^{e}	61.03^{e}	65.11^{e}

Table 4.2.27: Dry weight of turfgrass clippings after mowing at 60 DAS during summer season at different locations

Treatments	Dose (kg ha^{-1})	Dry weight of clippings (g m^{-2})		
		Location IV	Location V	Location VI
Isoproturon	0.937	47.12^{bc}	37.64^{c}	38.37^{cd}
Mesosulfuron + Iodosulfuron	0.014	44.65^{cde}	36.62^{cd}	42.87^{ab}
Clodinafop + Metribuzin	0.216	49.12^{ab}	40.65^{b}	41.08^{b}
2,4-D amine	0.500	42.67^{de}	34.63^{e}	33.87^{e}
Bispyribac sodium	0.025	45.16^{cde}	43.63^{a}	42.87^{ab}
Metribuzin	0.120	47.62^{bc}	36.64^{cd}	39.28^{cd}
Metsulfuron	0.005	45.65^{bcd}	34.62^{e}	38.38^{cd}
Carfentrazone-ethyl	0.020	45.14^{cde}	34.15^{e}	38.81^{cd}
Metsulfuron + Carfentrazone-ethyl	0.025	47.17^{bc}	35.13^{de}	40.63^{bc}
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	45.66^{bcd}	34.63^{e}	37.93^{cd}
Ethoxysulfuron	0.018	43.65^{de}	34.14^{e}	36.57^{de}
Halosulfuron	0.050	43.65^{de}	34.62^{e}	36.12^{de}
Atrazine	1.000	42.62^{de}	34.90^{de}	36.34^{de}
Two hand weedings (15 days interval)	-	52.63^{a}	42.63^{a}	45.58^{a}
Un-weeded (control)	-	39.64^{e}	30.51^{e}	29.36^{e}

4.2.20: Dry weight of turfgrass clippings after mowing at different locations

The dry weight of turfgrass clippings was calculated at 60 DAS after mowing and presented in Table 4.2.27. Among the herbicides, two hand weedings resulted in obtaining the maximum dry weight followed by clodinafop + metribuzin @ 0.216 kg ha^{-1} at Location IV, bispyribac sodium @ 0.025 kg ha^{-1} @ Location V, mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1} and bispyribac sodium @ 0.025 kg ha^{-1} at Location VI. Minimum dry weight of turfgrass was recorded in un-weeded control. The dry weight of turfgrass varied as per the weed density as presented in different Tables (Table 4.2.1. to Table 4.2.11.) and total dry weight of weeds (Table 4.2.21.) The maximum dry weight of clippings was exhibited by treatments having less weeds and more weed control efficiency.

The total weed dry weight and dry weight of turfgrass clippings in lawn during summer season was negatively correlated at 60 DAS after mowing. The presence of weeds had affected the dry weight of turfgrass (66 - 83 %) at all the locations (Fig. 4).

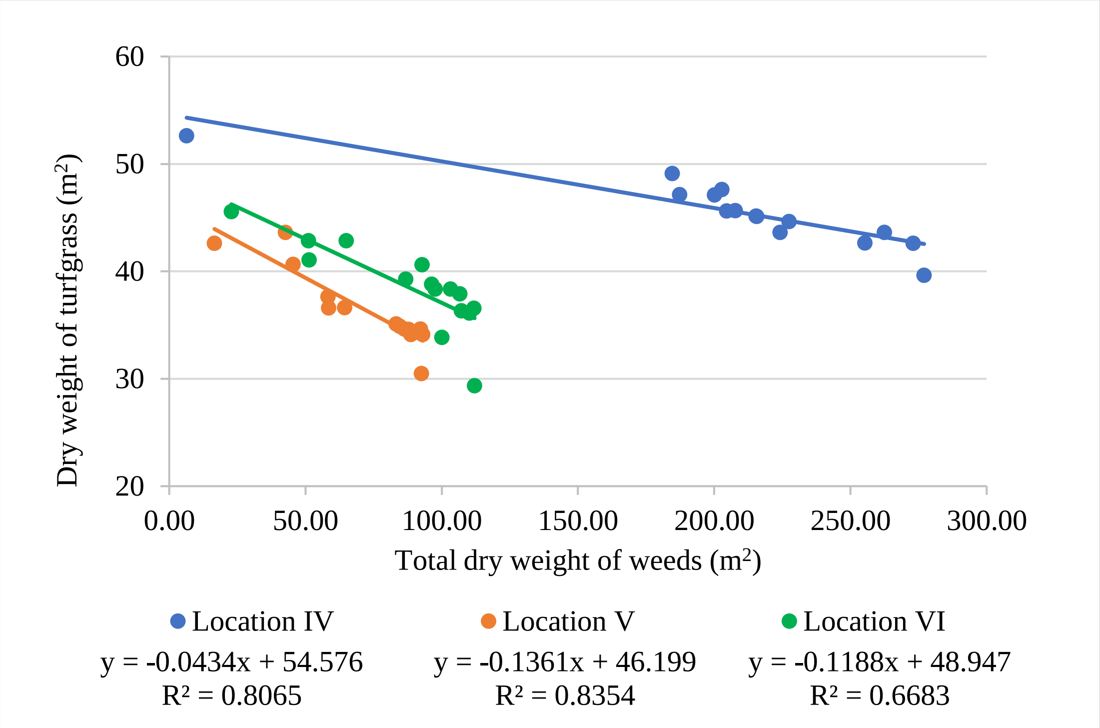

Fig. 4: Correlation of dry weight of weeds and dry weight of turfgrass during summer season.

4.2.21: Effect of post-emergence herbicides on turfgrass injury

The turfgrass injury ratings recorded weekly using scale 1-9, (where 9 was attributed no injury and 1 as completely necrotic) are presented in Table 4.2.28. The study revealed that grasses, broadleaf weeds and sedges were controlled very effectively with use of herbicide treatments at different locations without showing any toxic symptoms on the turfgrass. Due to more fresh and dry weight of weeds during this season, there was no observation of turfgrass injury.

Table 4.2.28: Effect of post-emergence herbicides on turfgrass injury during summer season

Treatments	Dose (kg ha^{-1})	Turfgrass injury				
		0 DAS	7 DAS	14 DAS	21 DAS	28 DAS
Isoproturon	0.937	9	9	9	9	9
Mesosulfuron + Iodosulfuron	0.014	9	9	9	9	9
Clodinafop + Metribuzin	0.216	9	9	9	9	9
2,4-D amine	0.500	9	9	9	9	9
Bispyribac sodium	0.025	9	9	9	9	9
Metribuzin	0.120	9	9	9	9	9
Metsulfuron	0.005	9	9	9	9	9
Carfentrazone-ethyl	0.020	9	9	9	9	9
Metsulfuron + Carfentrazone-ethyl	0.025	9	9	9	9	9
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	9	9	9	9	9
Ethoxysulfuron	0.018	9	9	9	9	9
Halosulfuron	0.050	9	9	9	9	9
Atrazine	1.000	9	9	9	9	9
Two hand weedings (15 days interval)	-	9	9	9	9	9
Un-weeded (control)	-	9	9	9	9	9

Table 4.2.29: Phytotoxicity of post-emergence herbicides in lawn during summer season

Treatments	Dose (kg ha^{-1})	Phytotoxicity (0-10 scale)				
		3 DAS	7 DAS	10 DAS	15 DAS	25 DAS
Isoproturon	0.937	0	0	0	0	0
Mesosulfuron + Iodosulfuron	0.014	0	0	0	0	0
Clodinafop + Metribuzin	0.216	0	0	0	0	0
2,4-D amine	0.5	0	0	0	0	0
Bispyribac sodium	0.025	0	0	0	0	0
Metribuzin	0.120	0	0	0	0	0
Metsulfuron	0.005	0	0	0	0	0
Carfentrazone-ethyl	0.020	0	0	0	0	0
Metsulfuron + Carfentrazone-ethyl	0.025	0	0	0	0	0
Metsulfuron-methyl + Chlorimuron-ethyl	0.004	0	0	0	0	0
Ethoxysulfuron	0.018	0	0	0	0	0
Halosulfuron	0.050	0	0	0	0	0
Atrazine	1.0	0	0	0	0	0
Two hand weedings (15 days interval)	-	0	0	0	0	0
Un-weeded (control)	-	0	0	0	0	0

4.2.22: Phytotoxicity of post-emergence herbicides in lawn during summer season

The phytotoxicity rating recorded at 3, 7, 10, 15 and 25 days after application of herbicides in lawn during summer season at different locations are presented in Table 4.2.29. The study revealed that grasses, broadleaf weeds and sedges were controlled very effectively with use of herbicide treatments at different locations without any phytotoxicity effect on the turfgrass. Due to more fresh and dry weight of weeds before herbicide spray during this season, there was no observation of phytotoxicity. The results are in conformity with the findings of Singh (2018).

4.3: Economics

The data on cost of weeding and also savings in weeding cost compared to manual weeding in lawn are presented in Annexure I. Among herbicide treatments saving in weeding cost over hand weeding (Rs. 13102 ha^{-1}) was recorded in isoproturon @ 0.937 kg ha^{-1} for control of *Poa annua* and bispyribac sodium @ 0.025 kg ha^{-1} for *Dicanthium annulatum* Rs. 12852 ha^{-1} saved over hand weeding. Saving in weeding cost over hand weeding (Rs. 13427 ha^{-1}) was recorded in metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} which is performed significantly better than other treatments for control of broadleaf weeds. Saving in weeding cost over hand weeding (Rs. 12112 ha^{-1}) was recorded in halosulfuron @ 0.050 kg ha^{-1} which is performed significantly better than other treatments for control of sedges (*Cyperus rotundus*). Under present conditions of labour scarcity and higher labour wages, the use of herbicides resulted in lower cost on weed management with considerable savings in weeding cost. The results are in conformity with the findings of Siddappa *et al* (2015b) and Singh (2018).

CHAPTER - V

SUMMARY

The findings of present investigation entitled "Effect of post-emergence herbicides on weed control in lawn (C*ynodon dactylon* L.) Selection No. 1" are summarized as below:

5.1: Winter season

5.1.1: Weed flora

- The weed flora observed at different locations consisted of grasses, broadleaf weeds and sedges. The predominant weed specie among grasses was *Poa annua*; among broadleaf weeds were *Gnaphalium purpureum*, *Oxalis corniculata*, *Veronica agrestis, Desmodium triflorum*, *Coronopus didymus*, *Erigeron canadensis* and *Stellaria media*; among sedges was *Cyperus rotundus*. The mean density of 23.1 per cent was recorded in grasses, whereas broadleaf and sedges recorded 71.1 per cent and 5.8 per cent density respectively.

5.1.2: Reduction in weed dry weight

- Isoproturon @ 0.937 kg ha^{-1}, mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1}, clodinafop + metribuzin @ 0.216 kg ha^{-1}, bispyribac sodium @ 0.025 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1} and ethoxysulfuron @ 0.018 kg ha^{-1} recorded the lowest dry weight of grass weeds.
- Metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} recorded the lowest dry weight in broadleaf weeds upto 60 DAS.
- Halosulfuron @ 0.050 kg ha^{-1} recorded the lowest dry weight of sedge weeds upto 45 DAS. Metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} significantly lowered the total dry weight of weeds as compared with all other treatments in winter season.

5.1.3: Weed control efficiency (WCE)

- Highest per cent WCE was recorded as 85.5 and 89 per cent in metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and two hand weeding treatment, respectively. The WCE of 70.9 and 70.8 per cent was obtained in atrazine @ 1.0 kg ha^{-1} and metsulfuron @ 0.005 kg ha^{-1}, respectively.

5.1.4: Turfgrass performance

- Sward height of turfgrass was measured highest in hand weeding treatment followed by metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1}, atrazine @ 1.0 kg ha^{-1}, metsulfuron at 0.005 kg ha^{-1}, carfentrazone-ethyl @ 0.020 kg ha^{-1} and the lowest sward height was recorded in weedy check.
- Maximum dry weight of turfgrass clippings after mowing was found in metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and isoproturon @ 0.937 kg ha^{-1}. The dry weight of clippings was negatively correlated with the density of weeds.

- None of the herbicide found to be phytotoxic except in clodinafop + metribuzin @ 0.216 kg ha^{-1} which showed slight injury and discoloration of topmost leaves and recovered after 35 DAS recorded from visual observation.

5.1.5: Promising herbicides

- Isoproturon @ 0.937 kg ha^{-1}, mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1}, clodinafop + metribuzin @ 0.216 kg ha^{-1}, bispyribac sodium @ 0.025 kg ha^{-1}, metribuzin @ 0.120 kg ha^{-1}, ethoxysulfuron @ 0.018 kg ha^{-1} provided complete control of *Poa annua* which was observed at par with hand weeding. The density of *Poa annua* was recorded significantly less as compared with all other herbicides and weedy check at all the locations.
- Metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} provided complete control of *Gnaphalium purpureum*, *Oxalis corniculata*, *Veronica agrestis*, *Desmodium triflorum*, *Coronopus didymus*, *Erigeron canadensis* and *Stellaria media* upto 60 DAS which was significantly less as compared to all other herbicide treatments and weedy check at all the locations.
- Halosulfuron @ 0.050 kg ha^{-1} provided complete control of *Cyperus rotundus* upto 45 DAS, however, the weed re-sprouted 60 DAS.

5.2: Summer season

5.2.1: Weed flora

- The weed flora observed in the experimental sites at different locations consisted of grasses, broadleaf weeds and sedges. The predominant species among grasses were *Digitaria sanguinalis*, *Dicanthium annulatum*, *Dactyloctenium aegyptium* and *Paspalum dilatatum*; among broadleaf weeds were *Boerhavia diffusa*, *Alysicarpus vaginalis*, *Evolvulus nummularius* and *Desmodium triflorum* and among sedges was *Cyperus rotundus*. The average density of grass weeds was 59.2 per cent, whereas for broadleaf weeds and sedges, the mean weed density was 34.4 per cent and 6.4 per cent respectively.

5.2.2: Reduction in weed dry weight

- Clodinafop + metribuzin @ 0.216 kg ha^{-1} effectively reduced the dry weight of grass weeds at all the locations. Bispyribac sodium @ 0.025 kg ha^{-1} recorded lowest dry weight in *Dicanthium annulatum*.
- Metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} provided better control of broadleaf weeds and was observed at par with clodinafop + metribuzin @ 0.216 kg ha^{-1} and mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1}.
- Halosulfuron @ 0.050 kg ha^{-1} was found effective decreased the sedges dry weight upto 45 DAS.

5.2.3: Weed control efficiency (WCE)

- The WCE in clodinafop + metribuzin @ 0.216 kg ha^{-1}, bispyribac sodium @ 0.025 kg ha^{-1} and hand weeding treatment was recorded 46.2, 43.5 and 86.5 per cent, respectively.

5.2.4: Turfgrass performance

- Two hand weeding treatments showed significantly more sward height as compared with weedy check and other treatments at all locations. Second best treatments were metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} and clodinafop + metribuzin @ 0.216 kg ha^{-1} and bispyribac sodium @ 0.025 kg ha^{-1}.
- Dry weight of turfgrass clippings was recorded highest in two hand weedings followed by clodinafop + metribuzin @ 0.216 kg ha^{-1} ,bispyribac sodium @ 0.025 kg ha^{-1} and mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1}. Lowest dry weight of turfgrass was recorded in un-weeded control.
- Due to more growth of weeds during this season, there was no observation of phytotoxicity over turfgrass in any of the herbicide sprays.

5.2.5: Promising herbicides

- Bispyribac sodium @ 0.025 kg ha^{-1} provided complete control of *Dicanthium annulatum* upto 60 DAS.
- The lowest weed density of *Digitaria sanguinalis* and *Dactyloctenium aegyptium* was recorded in clodinafop + metribuzin @ 0.216 kg ha^{-1} as compared with other herbicides. Weed density of *Paspalum dilatatum* was reduced by mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1}.
- Metsulfuron + carfentrazone-ethyl @ 0.025 kg ha^{-1} provided complete control for *Boerhavia diffusa*, *Alysicarpus vaginalis* and *Desmodium triflorum* upto 60 DAS whereas it suppressed the *Evolvulus nummularius*. Two hand weedings provided complete control of *Evolvulus nummularius* weed upto 45 DAS.
- Halosulfuron @ 0.050 kg ha^{-1} provided complete control of *Cyperus rotundus* upto 45 DAS and the weed re-sprouted when observed at 60 DAS.

5.3: Conclusion

From the results of the present investigation, it is concluded that clodinafop + metribuzin @ 0.216 kg ha^{-1} reduced the density and dry weight of *Digitaria sanguinalis* and *Dactyloctenium aegyptium*. Isoproturon @ 0.937 kg ha^{-1} provided complete control of *Poaannua* whereas bispyribac sodium @ 0.025 kg ha^{-1} provided complete control of *Dicanthiumannulatum* upto 60 DAS. Weed density and dry weight of *Paspalum dilatatum* weed wasaffected by mesosulfuron + iodosulfuron @ 0.014 kg ha^{-1}. Metsulfuron + carfentrazone-ethyl@ 0.025 kg ha^{-1} provided complete control of broad leaf weeds such as *Gnaphalium purpureum*,*Oxalis corniculata*, *Veronica agrestis*, *Desmodium triflorum*, *Coronopusdidymus*, *Erigeroncanadensis*, *Stellaria media*, *Boerhaviadiffusa*, *Alysicarpus vaginalis* and *Desmodiumtriflorum* upto 60 DAS. Halosulfuron @ 0.050 kg ha^{-1} provided complete control of *Cyperusrotundus* upto 45 DAS. Among all herbicides WCE was recorded highest in metsulfuron +carfentrazone-ethyl @ 0.025 kg ha^{-1} (85.5%) in winter season whereas in summer season it washighest in clodinafop + metribuzin @ 0.216 kg (46.2 %) and bispyribac sodium @ 0.025 kgha^{-1} (43.5 %). Sward height and dry weight of turfgrass was negatively correlated with thepresence of weeds. Phytotoxicity was observed in clodinafop + metribuzin @ 0.216 kg ha^{-1}however, the turfgrass recovered at 35 DAS in winter season whereas in summer season therewas no observation of phytotoxicity. Turfgrass colour rating was ranked 8 at all the locationsduring both the seasons.

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ANNEXURE I

Economics of different weed control treatments in a lawn of one hectare

Treat-ments	Name of the herbicide	Brand name of herbicide	Dose (kg ha^{-1}) a.i.	Commercial dose (kg ha^{-1})	Cost of herbicide (Rs. ha^{-1})	Cost of manpower (Rs. ha^{-1})	Total expenditure (Rs. ha^{-1})	Cost of saving over hand weeding (Rs. ha^{-1})
T1	Isoproturon	Iso 75 WP	0.937	1.250	1250	368	1618	13102
T2	Mesosulfuron + iodosulfuron	Atlantis 3.6 WDG	0.014	0.390	1625	368	1993	12727
T3	Clodinafop + metribuzin	Shagun 21-11	0.216	0.400	1875	368	2243	12477
T4	2,4-D amine	Punch 58 SL	0.500	0.800	435	368	803	13917
T5	Bispyribac-sodium	Nominee gold 10 SC	0.025	0.250	1500	368	1868	12852
T6	Metribuzin	Sencor 70 WP	0.120	0.180	360	368	728	13992
T7	Metsulfuron-methyl	Algrip 20 WP	0.005	0.025	300	368	668	14052
T8	Carfentrazone-ethyl	Affinity 40 DF	0.020	0.050	625	368	993	13727
T9	Metsulfuron + carfentrazone-ethyl	Lanfida 50 DF	0.025	0.075	925	368	1293	13427
T10	Metsulfuron-methyl + chlorimuron-ethyl	Almix 20 WP	0.004	0.020	500	368	868	13852
T11	Ethoxysulfuron	Sunrice 15 WG	0.018	0.120	1080	368	1448	13272
T12	Halosulfuron	Sempra 75 WG	0.050	0.060	2240	368	2608	12112
T13	Atrazine	Atrataf 50 WP	1.000	2.000	720	368	1088	13632
T14	Two hand weedings (at 15 days interval)	-	-	-	-	14720*	14720	0
T15	Un-weeded (control)	-	-	-	-	-	-	

*Calculated based on requirement of 40 man-days for two hand weedings in a lawn of one hectare area

ANNEXURE II

Meteorological data during the experimental period at Punjab Agricultural University, Ludhiana (2021)

Week	Temperature (ºC)			Mean Relative Humidity (%)	Rainfall (mm)	Rainy Days (number)	Evaporation (mm)
	Maximum	Minimum	Mean				
9	27.9	11.9	19.9	68.4	0.0	0	24.3
10	29.7	15.3	22.5	61.1	0.0	0	25.4
11	28.7	15.3	22.0	60.4	0.0	0	23.0
12	29.1	15.2	22.1	59.8	5.0	1	28.6
13	32.3	15.7	24.0	48.6	0.0	0	34.6
14	32.3	14.7	23.5	36.2	3.0	1	41.6
15	36.1	17.5	26.8	30.2	0.0	0	50.8
16	32.1	17.9	25.0	48.2	6.6	1	41.4
17	36.2	18.1	27.2	44.9	4.7	1	44.6
18	39.0	21.4	30.2	41.0	0.0	0	7.2
31	32.6	27.1	29.8	79.6	69.0	3	16.6
32	34.1	26.8	30.5	72.5	1.0	0	28.2
33	35.3	28.1	31.7	65.8	0.0	0	35.6
34	32.4	27.2	29.8	77.3	37.6	1	32.4
35	34.1	26.1	30.1	68.4	0.0	0	28.8
36	32.2	26.9	29.6	76.3	16.2	1	22.4
37	31.6	25.3	28.5	76.1	146.8	4	20.8
38	29.8	24.7	27.2	82.7	132.8	4	18.9
39	32.9	24.7	28.8	75.8	0.0	0	18.6

ANNEXURE III

Chemical name, formula and mechanism of action of different herbicides used in the experiment

S.No.	Name of Herbicide	Chemical Name IUPAC	Empirical Formula	Mechanism of Action
1.	Isoproturon	3-(4-Isopropylphenyl)-1,1-dimethylurea	$C_{12}H_{18}N_2O$	Inhibits photosynthesis at photo system II
2.	Mesosulfuron + Iodosulfuron	2-[(4,6-dimethoxypyrimidin-2-yl) carbamoylsulfamoyl]-4-(methanesulfonamidomethyl) benzoic Acid + 4-iodo-2-[(4-methoxy-6-methyl-1,3,5-triazin-2-yl) carbamoylsulfamoyl] benzoic acid	$C_{16}H_{19}N_5O_9S_2$ + $C_{13}H_{12}IN_5O_6S$	Inhibits enzyme aceto hydroxy acid synthase (AHAS). Both the actives are phloem-xylem mobile in the target weed both via the foliage and via the soil
3.	Clodinafop + Metribuzin	(2R)-2-[4-[(5-Chloro-3-fluoro-2-pyridinyl) oxy] phenoxy] propanoic Acid + 4-amino-6-tert-butyl-3-methylsulfanyl-1,2,4-triazin-5-one	$C_{14}H_{11}ClFNO_4$ + $C_8H_{14}N_4OS$	Clodinafop: Inhibits the acetyl co-enzyme A carboxylase (ACCase) enzyme, and Metribuzin: Inhibits photosystem II of photosynthesis
4.	2,4-D amine	2-(2,4-dichlorophenoxy)acetic acid;N-methyl methanamine	$C_{10}H_{13}Cl_2NO_3$	Mimicking the plant growth hormone auxin (indole acetic acid)
5.	Bispyribac- sodium	Sodium 2, 6-bis [(4, 6-dimethoxypyrimidin-2-yl) oxy] benzoate	$C_{19}H_{17}N_4NaO_8$	Inhibits acetolactate synthase (ALS) or AHAS (aceto hydroxy acid synthase) enzyme
6.	Metribuzin	4-amino-6-tert-butyl-3-methylsulfanyl-1,2,4-triazin-5-one	$C_8H_{14}N_4OS$	Inhibits photosystem II of photosynthesis
7.	Metsulfuron	methyl 2-[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)carbamoylsulfamoyl] benzoate	$C_{14}H_{15}N_5O_6S$	Inhibits cell division in the shoots and roots of the plant

S.No.	Name of Herbicide	Chemical Name IUPAC	Empirical Formula	Mechanism of Action
8.	Carfentrazone-ethyl	ethyl 2-chloro-3-[2-chloro-5-[4-(difluoromethyl)-3-methyl-5-oxo-1,2,4-triazol-1-yl]-4-fluorophenyl]propanoate	$C_{15}H_{14}Cl_2F_3N_3O_3$	Inhibits the action of protoporphyrinogen oxidase (PPO) and disruption of membranes causing cell death
9.	Metsulfuron + Carfentrazone-ethyl	methyl 2-[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)carbamoylsulfamoyl] benzoate + ethyl 2-chloro-3-[2-chloro-5-[4-(difluoromethyl)-3-methyl-5-oxo-1,2,4-triazol-1-yl]-4-fluorophenyl]propanoate	$C_{14}H_{15}N_5O_6S$ + $C_{15}H_{14}Cl_2F_3N_3O_3$	Metsulfuron: Inhibits cell division in the shoots and roots of the plant. Carfentrazone: Inhibits the action of protoporphyrinogen oxidase (PPO) causing cell death.
10.	Metsulfuron-methyl + Chlorimuron-ethyl	methyl 2-[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)carbamoylsulfamoyl]benzoate + ethyl 2-[(4-chloro-6-methoxypyrimidin-2-yl)carbamoylsulfamoyl]benzoate	$C_{14}H_{15}N_5O_6S$ + $C_{15}H_{15}ClN_4O_6S$	Metsulfuron: Inhibits cell division in the shoots and roots of the plant. Chlorimuron: Inhibits biosynthesis of the essential amino acids valine and isoleucine
11.	Ethoxysulfuron	(2-ethoxyphenyl) N-[(4,6-dimethoxypyrimidin-2-yl)carbamoyl] sulfamate	$C_{15}H_{18}N_4O_7S$	Inhibits ALS (acetolactate synthase) enzyme
12.	Halosulfuron	methyl 3-chloro-5-[(4,6-dimethoxypyrimidin-2-yl) carbamoylsulfamoyl]-1-methylpyrazole-4-carboxylate	$C_{13}H_{15}ClN_6O_7S$	Inhibits the enzyme acetolactate synthase (ALS) and slow down cell division at all growth phases
13.	Atrazine	6-chloro-4-N-ethyl-2-N-propan-2-yl-1,3,5-triazine-2,4-diamine	$C_8H_{14}ClN_5$	Binding to the plastoquinone-binding protein in photosystem II and breakdown in electron transport process

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EDUCATIONAL QUALIFICATIONS

Bachelor's Degree	:	**B.Sc. Agri. (Hons) 6 year programme**
University and year of award	:	Punjab Agricultural University, Ludhiana 2019
OCPA	:	6.52/10
Master's Degree	:	**M.Sc. Horticulture (Floriculture and Landscaping)**
University and year of award	:	Punjab Agricultural University, Ludhiana 2022
OCPA	:	7.69/10
Title of Master's Thesis	:	Effect of post-emergence herbicides on weed control in lawn (C*ynodon dactylon* L.) Selection No. 1