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EFFECT OF FERTILITY LEVELS AND WEED MANAGEMENT PRACTICES ON WEED DYNAMICS AND CONTROL EFFICIENCY IN LINSEED (*LINUM USITATISSIMUM* L.)

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ABSTRACT

Field experiments during *Rabi* season 2016-17 and 2017-18 at Rajasthan Agricultural Research Institute, Durgapura, evaluated weed characteristics in linseed under four fertility levels (75%, 100%, 125%, 150% RDF) and seven weed management practices (weedy check, hand weeding at 20-25 DAS, Pendimethalin 30 EC @ 0.75 kg a.i. ha^{-1} PE, Pendimethalin 38.7 CS @ 0.75 kg a.i. ha^{-1} PE, Clodinafop propargyl 15 WP @ 60 g a.i. ha^{-1} PoE 20-25 DAS, Imazethapyr 10 SL @ 40 g a.i. ha^{-1} PoE 20-25 DAS, weed free) in factorial RBD with three replications. Weed free treatment recorded minimum density (0.71 m^{-2}) and dry weight (0.71 g m^{-2}) of major weeds like *Chenopodium album, C. murale, Asphodelus tenuifolius.* Pendimethalin 38.7 CS was next best, reducing total weed density by 57-68% and dry weight by 45% over weedy check. It achieved ~70% weed control efficiency, lowest weed index, and highest rating (7.42/10), confirming its superiority for broadleaf and grassy weed suppression on loamy sand soils.

Keywords **:** Clodinafop-propargyl, Imazethapyr, Linseed, Pendimethalin, post emergence, pre-emergence, Weed management.

Introduction

Linseed (*Linum usitatissimum* L.) productivity is greatly affected by weed infestation, particularly during the early stages of crop growth. Weeds compete aggressively with linseed for essential resources such as nutrients, moisture, space, aeration, and light. The crop exhibits slow initial growth, making it highly susceptible to weed competition during the critical period of 20 to 50 days after sowing (Ghosh *et al*., 2020). Uncontrolled weed growth during this period can cause severe yield losses, which may range from 42 to 45 per cent depending on weed intensity (Biradar *et al*., 2016).

Effective weed management is therefore essential to realize optimum crop productivity. Weed-free conditions not only enhance seed yield but also facilitate harvesting and reduce processing difficulties and production costs (Siddesh *et al*., 2016). However, under farmers' field conditions, the yield potential of linseed is seldom achieved due to constraints such as inadequate nutrient management, limited soil moisture, labour scarcity, and severe weed infestation. Manual weeding, though effective, is labour-intensive and often impractical due to the high cost and non-availability of labour at critical stages.

Herbicide-based weed management offers a practical and efficient alternative to manual weeding in linseed. Several pre- and post-emergence herbicides such as Pendimethalin, Clodinafop, and Imazethapyr have been reported to provide effective control of major weed flora when applied at appropriate doses and stages (Siddesh *et al*., 2016). Despite this, linseed being a minor crop, limited research especially in Rajasthan has examined the combined influence of fertility levels and weed management practices on weed dynamics and crop safety.

Therefore, the present investigation was undertaken to evaluate different weed management practices under varying fertilizer doses, with specific emphasis on weed density, weed dry matter, weed control efficiency, weed index, and phytotoxicity in linseed, with the aim of identifying an effective and sustainable weed management strategy.

Materials and Methods

The field experiment on the effect of fertility levels and weed management practices on linseed (*Linum usitatissimum* L.) growth, yield and quality was conducted during Rabi 2016-17 and 2017-18 at Rajasthan Agricultural Research Institute, Durgapura, Jaipur (26°51' N, 75°47' E, 390 m), a semi-arid zone, on loamy sand soil (0-30 cm) low in organic carbon (0.26-0.27%) and N (139-143 kg ha^{-1}), medium in P (30-33 kg ha^{-1}) and K (192-206 kg ha^{-1}), pH 8.2-8.3. A factorial RBD with 3 replications tested 28 treatments four fertility levels i.e. F_1- 75 % RDF, F_2- 100 % RDF, F_3- 125 % RDF, F_4- 150 % RDF and second factor was seven weed management practices i.e W_1- Control (Weedy check), W_2- One hand weeding 20-25 DAS, W_3- Pendimethalin 30 EC @ 0.75 a.i. kg ha^{-1} as P.E, W_4- Pendimethalin 38.7 CS @ 0.75 a.i. kg ha^{-1} as P.E, W_5- Clodinafop-propargyl 15 WP @ 60 a.i. g ha^{-1} at 20-25 DAS, W_6- Imazethapyr 10 SL @ 40 a.i. g ha^{-1} at 20-25 DAS and W_7- Weed free, in 3.9×5.0 m gross plots (net 2.7×4 m, 30 cm rows); Parvati variety sown manually at 20 kg ha^{-1} (3 cm depth), with basal half N + full P, remaining N at 30 DAS post-weed management, herbicide application via knapsack sprayer, sprinkler irrigation (pre-sowing + 30-38 day intervals) .Data square-root transformed for weeds, analyzed by ANOVA with SE/CD at 5% (Panse and Sukhatme,1985).

Weed density

Weed density of each weed species was observed at 30 and 60 DAS from five random spots in each plot by counting the number of weeds per quadrate 2500 cm^2 and average was calculated. This average value was multiplied with four to have weed density/m^2. Weed density is also known as absolute density of a species. For drawing the valid conclusions, the weed count data were subjected to square root transformation $\left(\sqrt{(x+0.5)}\right)$ as suggested by Blackman and Roberts (1950) before subjecting to statistical analysis.

Dry weight of weeds

Weeds samples from two randomly selected spots in each plot were taken at 30 and 60 DAS with the help of quadrate 2500 cm^2 and the average was worked out. The average value was multiplied by four to have weed dry weight (g/m^2). The collected samples were subjected to oven dry, weighed and average was calculated.

Weed control efficiency (%)

In order to evaluate the weed control treatments for their efficacy, weed control efficiency of each treatment at 30 and 60 DAS was calculated by using the following formula. (Kondap and Upadhyay, 1985).

$$WCE = \frac{DWC - DWT}{DWC} \times 100$$

Where,

WCE = Weed control efficiency (%)

DWC = Dry weight of weeds in weedy check

DWT = Dry weight of weeds in treated check

Weed Index (%)

Weed index is a derived parameter from the crop yields obtained across the treatments of weed control researches (Gill and Kumar, 1969). It is a measure of the crop yield loss accrued across treatments in comparison to a weed free plot adopted in an experiment.

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

Where,
WI = Weed index
X = Crop yield in weed free plot
Y = Crop yield in treated plot for which WI is worked out

Phyto-toxicity rating on crops (0-10 scale)

Herbicides on application to crop field produce certain phyto-toxicity symptoms mainly on weeds and in some cases on crop plants too. Injury to crop indicates the degree of herbicide's selectivity to crop and tells about whether it could safely be used in that crop. For convenience in recording phyto-toxicity in the field, first percent injury in experimental crop and residual experimental crop compared over control may be judged or apprehended visually and then rating was executed on the scale.

Table 1: Qualitative description of phyto-toxicity effect of applied herbicides on weeds and crop in the visual scoring scale of 0 to 10 (Rao, 1986).

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

Weed control rating (0-10 scale)

Weed control rating indicates the degree up to which weeds were controlled by the herbicidal spray. It was calculated after 15 days of spray and was compared over control and then rating was executed on the scale. Scale of weed control rating of 0-10 was referred as per above mention table.

Results

Density of *Chenopodium album*

Data presented in Fig. 1 revealed that density of *Chenopodium album* could not be affected significantly with the fertility levels during both consecutive years. Among the treatments (Fig. 1), weed free W_7 recorded significantly minimum density of *Chenopodium album* i.e. 0.71 and 0.71 m^{-2} over treatment W_1 (13.33 and 12.39 m^{-2}) during 2016-17 and 2017-18, respectively. Likewise, In chemical weed control, application of Pendimethalin 38.7 CS @ 0.75 a.i. kg ha^{-1} as P.E (W_4) recorded statistically lower density of *Chenopodium album* i.e. 3.65 and 3.79 m^{-2} over other chemical weed management practices and weedy check (W_1).

Density of *Chenopodium murale*

According to data presented in Fig. 2 revealed that density of *Chenopodium murale* could not be affected significantly with the fertility levels during both consecutive years. Among weed management practices weed free treatment W_7 recorded significantly minimum density of *Chenopodium murale* i.e. 0.71 and 0.71 m^{-2} over treatment W_1 (6.06 and 6.04 m^{-2}) during 2016-17 and 2017-18, respectively. Likewise, In chemical weed control, application of Pendimethalin 38.7 CS @ 0.75 a.i. kg ha^{-1} as P.E (W_4) recorded statistically lower density of *Chenopodium murale* i.e. 3.02 and 3.36 m^{-2} over other chemical weed management practices and weedy check (W_1).

Density of *Asphodelus tenuifolius*

There was no significant effect of fertility levels on density of *Asphodelus tenuifolius* during both consecutive years (Fig. 3). Among weed management practices treatment W_7 recorded significantly minimum density of *Asphodelus tenuifolius* i.e. 0.71 and 0.71 m^{-2} over treatment W_1 (3.44 and 2.92 m^{-2}) during 2016-17 and 2017-18, respectively. On the other hand, chemical weed control, application of Pendimethalin 38.7 CS @ 0.75 a.i. kg ha^{-1} as P.E (W_4) recorded statistically lower density of *Asphodelus tenuifolius* i.e. 1.91 and 1.74 m^{-2} over other chemical weed management practices and weedy check (W_1) during both the years of study.

Density of *Rumex dentatus*

Data presented in Fig. 4 revealed that density of *Rumex dentatus* could not be affected significantly with the fertility levels during both consecutive years. In weed management practices weed free treatment W_7 recorded significantly minimum density of *Rumex dentatus* i.e. 0.71 and 0.71 m^{-2} over treatment W_1 (4.12 and 3.10 m^{-2}) during 2016-17 and 2017-18, respectively. Likewise, In chemical weed control, application of Pendimethalin 38.7 CS @ 0.75 a.i. kg ha^{-1} as P.E (W_4) recorded statistically lower density of *Rumex dentatus* i.e. 1.64 and 1.56 m^{-2} over other chemical weed management practices and weedy check (W_1) during 2016-17 and 2017-18.

Density of *Argemone mexicana*

Fertility levels do not effect on Density of *Argemone mexicana* during both the years of study presented in (Fig. 5). Among different weed management practices treatment W_7 recorded significantly minimum density of *Argemone mexicana* i.e. 0.71 and 0.71 m^{-2} over treatment W_1 (2.29 and 2.40 m^{-2}) during 2016-17 and 2017-18, and in chemical weed management practices application of

Pendimethalin 38.7 CS @ 0.75 a.i. kg ha^{-1} as P.E (W_4) recorded statistically lower density of *Argemone mexicana* i.e. 1.45 and 1.28 m^{-2} over other chemical weed management practices and weedy check (W_1) during 2016-17 and 2017-18.

Density of *Cynodon dactylon*

Data presented in Fig. 6 revealed that density of *Cynodon dactylon* could not be affected significantly with the fertility levels during both consecutive years. In weed management practices weed free treatment W_7 recorded significantly minimum density of *Cynodon dactylon* i.e. 0.71 and 0.71 m^{-2} over treatment W_1 (5.98 and 5.76 m^{-2}) during 2016-17 and 2017-18, respectively. Likewise, In chemical weed control, application of Pendimethalin 38.7 CS @ 0.75 a.i. kg ha^{-1} as P.E (W_4) recorded statistically lower density of *Cynodon dactylon* i.e. 1.61 and 1.69 m^{-2} over other chemical weed management practices and weedy check (W_1) during 2016-17 and 2017-18.

Total weed density

There was no significant effect of fertility levels on total weed density (Table 2). Among weed management treatments W_7 recorded significantly minimum total weed density i.e. 0.71 and 0.71 m^{-2} during 2016-17 and 2017-18, respectively. In chemical weed management practices minimum weed density was observed in treatment W_4 (7.32 and 7.67 m^{-2}) as compared to treatment W_1 (23.48 and 22.41 m^{-2}).

Total dry weight of the weed (g m^{-2})

A perusal of data presented in Table 2 showed that the total dry weight of weeds could not be influenced significantly due to fertility levels during both the years of experimentation. Among the treatments weed free recorded significantly minimum total dry weight of weeds i.e. 0.71 and 0.71 g m^{-2}. In chemical weed management treatment W_4 recorded minimum weed dry weight (6.31 and 6.46 g m^{-2}) over treatment W_1 (11.46 and 11.72 g m^{-2}) during 2016-17 and 2017-18, respectively.

Weed control efficiency (%)

The data showed in table 2 revealed that, there was no significant effect of fertility levels on weed control efficiency during both the years of study. Among weed management practices maximum seed control efficiency was observed in treatment W_7 (100 and 100%) during the both the years of study. In chemical weed management treatment W_4 (69.70 and 69.69 %) over W_1 (0 and 0 %) during 2016-17 and 2017-18, respectively.

Weed index (%)

A perusal of data presented in Table 2 showed that the weed index could not be influenced significantly due to fertility levels during both the years of study. Among the treatments, weed free recorded significantly minimum weed index (0 and 0 %), and among chemical weed management minimum weed index was observed in treatment W_4 (7 and 6.97 %) over W_1 (29.96 and 30.26 %) during 2016-17 and 2017-18, respectively.

Weed control rating

Results drawn in the Table 2 indicated that the weed free check (10 and 10) recorded highest weed control rating. Among herbicide formulations, Pendimethalin 38.7 CS @ 0.75 kg a.i. ha^{-1} as PE (W_4) recorded higher weed control rating (7.33 and 7.50) over control W_1 (0.00 and 0.00) during 2016-17 and 2017-18, respectively.

Phyto-toxicity rating (1-10 scale)

Results drawn in the Table 2 indicated that the Clodinafop propargyl 15 WP @ 60 g a.i. ha^{-1} at 20-25 DAS (W_5) recorded lower phyto-toxicity rating (0.31 and 0.30) over Pendimethalin 30 EC @ 0.75 a.i. kg ha^{-1} as PE (W_3) (0.89 and 0.89) during both the years. No phyto-toxicity rating was recorded for weed free, one hand weeding at 20-25 DAS and weedy check during 2016-17 and 2017-18.

Discussion

Weed density, frequency, dominance and dry weight

Data presented that the application of fertility levels could not influence any significant variation to the weed studies viz., weed density, weed dry weight, weed index, weed control efficiency, phyto-toxicity rating and weed control rating at all phases of crop growth and on all weed species (Fig. 1-6 and table 2). Linseed crop performs competitive behavior to weeds for nutrient, moisture, light, air and space, therefore, fertilizers failed to boost up the growth of the weed species.

Regular weed survey during the course of experimentation showed that linseed crop was heavily invaded by various broad leaf, grassy and sedge weeds immediately with the crop emergence (Fig. 1-6). The prominent dicot weed species found to infest the experimental crop were *Chenopodium album, Chenopodium murale*, *Rumex dentatus* and *Argemone mexicana*. *Cyperus rotundus* and *Cynodon dactylon* were the major narrow leaf weed species noted to invade the crop.

The results indicated that all the weed management practices except weedy check caused significant reduction in weed density and dry weight of all weed species at all the stages of crop in comparison to weedy check treatment. These findings are in conformity with those reported by Mukherjee (2014) in mustard, Gupta and Kushwah (2016) in sesame and Teja and Duary (2015) in mustard.

Application of different herbicides viz., Pendimethalin 30 EC, Pendimethalin 38.7 CS, Clodinafop propargyl 15 WP and Imazethapyr 10% SL reduced the density and dry matter of different weed species and at different crop stages in comparison to weedy check. However, these herbicides varied in their performance among themselves too.

Lowest pooled density of weeds viz., *Chenopodium album*, *Chenopodium murale*, *Rumex dentatus* and *Argemone mexicana*. *Cyperus rotundus* and *Cynodon dactylon* and total weed density were observed under Pendimethalin 38.7 CS treatment. Weed free check recorded lowest weed density under observed weed flora followed by hand weeding which were at par with Pendimethalin 38.7 CS. Lowest pooled density of *Cynodon dactylon* and *Cyperus rotundus* at were observed under Pendimethalin 38.7 CS. These results corroborate the findings of Mukherjee (2014) in mustard, Tomar (2015) in mustard, Kalaichelvi and Kumar (2016) in castor, and Devendra *et al.* (2016) in linseed (Table 1).

Pendimethalin 38.7 CS treatment recorded the lowest total weed dry weight of weed free and hand weeding treatment which was at par with Pendimethalin 38.7 CS (Table 2).

The extent of weed control achieved with these herbicides seems to be due to their phyto-toxic action on weeds. Being a dinitroaniline, Pendimethalin exerts it herbicidal effect by inhibiting root and shoot growth of weed species when absorbed by them. It generally inhibits microtubule assembly during cell division. The inhibition of root growth is a direct and the most spectacular observable symptom following its root absorption. Reduced shoot growth is probably a secondary effect caused by limited root growth. Disruption of ATP formation either by interfering with energy generating mechanism or by blocking the energy transfer mechanism of mitochondria or by both is considered to be the primary mode of action of herbicides mainly the Pendimethalin in susceptible plant species (Wang *et al*., 1974). The adverse effect on RNA, DNA and protein synthesis and enzyme activities appears to be secondary. Its effectiveness can be further attributed to the fact that it controls broad leaf weeds more effectively than grasses. In the present study, the dicots are dominating weeds than monocots. Hence, the total weed control due to this herbicide was on superior side. Pendimethalin is known to be absorbed by germinating weeds and disrupts the cell division, especially mitotic process mostly in meristematic tissues of weeds which are responsible for lateral and secondary root formation (Ashton and crafts, 1973). Hence, thus it is fairly conceivable that such inhibitory effects of Pendimethalin might have reduced the weed population and weed dry matter production. The results are in close conformity with finding of Suganyadevi *et al*. (2012) in Rabi groundnut and Devendra *et al*. (2016) in linseed.

Weed control efficiency, weed index, weed control rating (0 10) and phyto-toxicity rating (0-10)

After weed free, the highest weed control efficiencies were recorded under hand weeding followed by Pendimethalin 38.7 CS. Similarly, the lowest weed index was observed under Pendimethalin 38.7 CS after weed free and hand weeding (Table 2). Better weed control which resulted into higher yield under these treatments showed improved weed indices. The results are on line with those of Kour *et al*. (2014) in chickpea+ mustard intercropping, Mahatale *et al*. (2014) in groundnut and Devendra *et al*. (2016) in linseed. Highest weed control rating (0-10 scale) was recorded under weed free check, hand weeding and Pendimethalin 38.7 CS followed by Pendimethalin 30 EC, Imazethapyr 10% SL and Clodinafop propargyl 15 WP. After weed free, weedy check and hand weeding, Pendimethalin 30 EC treatment recorded the highest phyto-toxicity rating followed by Pendimethalin 38.7 CS, Imazethapyr 10% SL and Clodinafop propargyl 15 WP (Table 2). Pendimethalin 30 EC and 38.7 CS exhibits negligible phyto-toxic effect on linseed crop due to its incompatibility with the crop which did not result any necrotic effect on linseed just after 10-15 days of its emergence.

Conclusion

Pre-emergence application of Pendimethalin 38.7 CS reduced the total weed density, weed dry matter and weed control efficiency most effectively in comparison to other herbicidal treatments after weed free and hand weeding at 20-25 DAS.

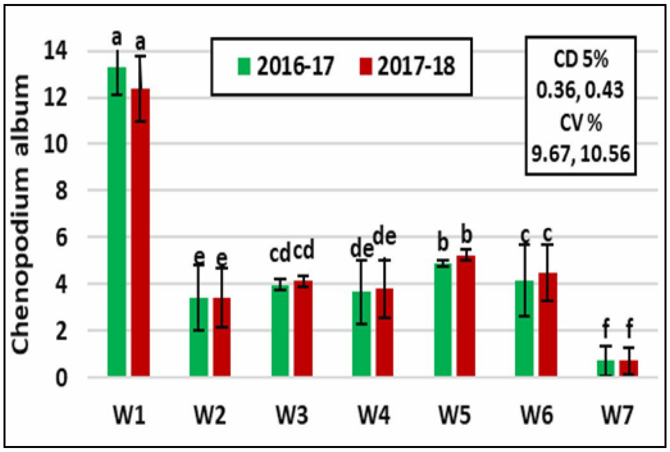

Fig. 1: Density of *Chenopodium album*

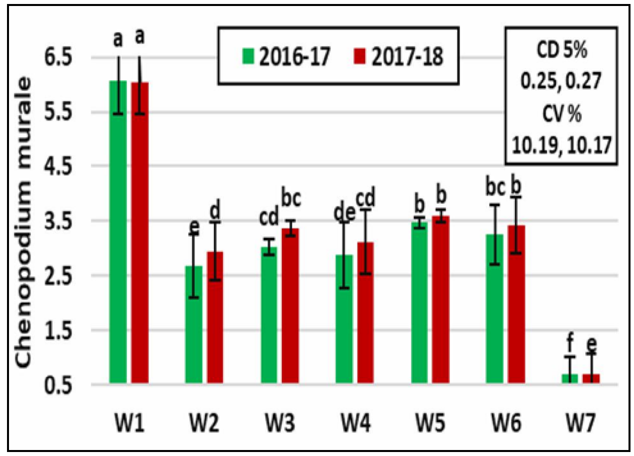

Fig. 2: Density of *Chenopodium murale*

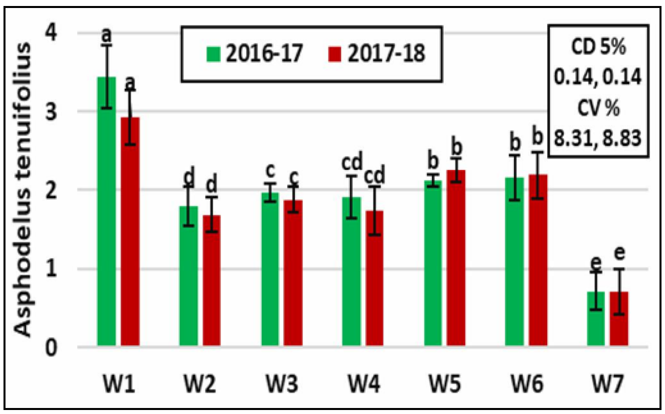

Fig. 3: Density of *Asphodelus tenuifolius*

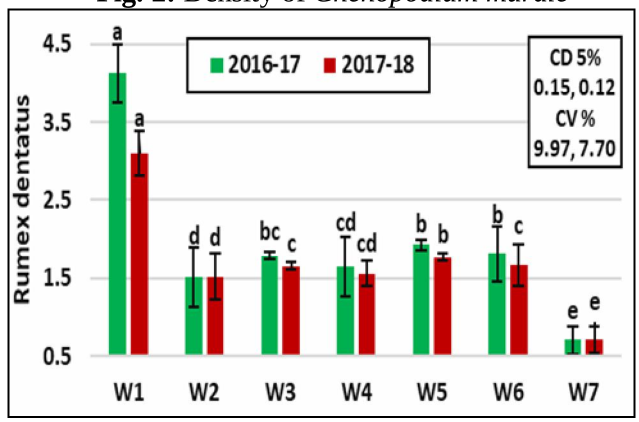

Fig. 4: Density of *Rumex dentatus*

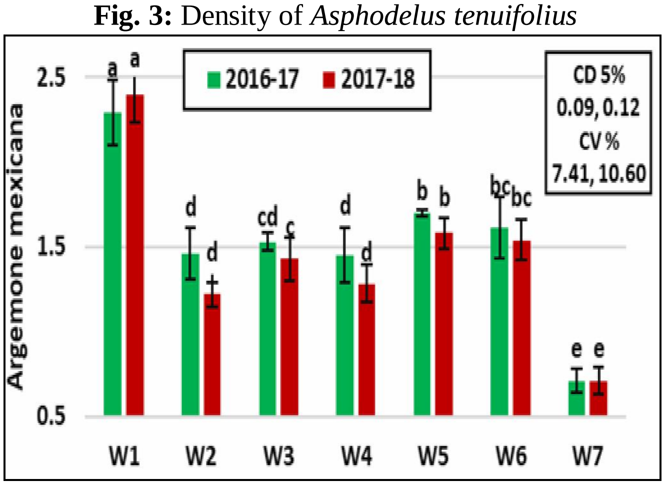

Fig. 5: Density of *Argemone mexicana*

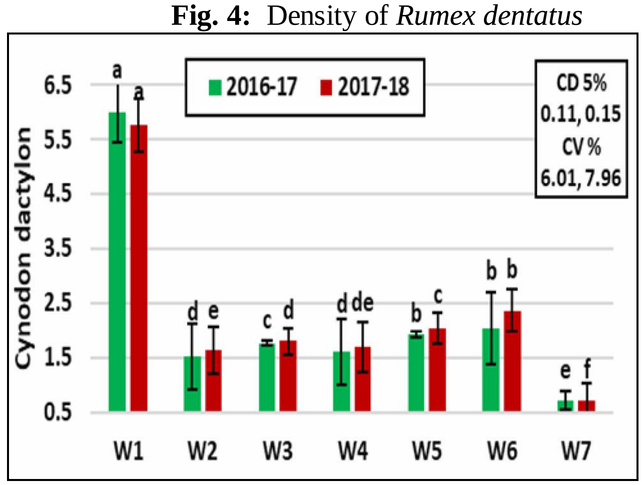

Fig. 6: Density of *Cynodon dactylon*

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