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Effect of Imidazolinones Alone and in Combination on Weed Dry Matter Accumulation in Pigeon Pea (*Cajanus cajan* L.)

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ABSTRACT

Background: Among pulse crops, pigeon pea [*Cajanus cajan* (L.) Millsp] is one of the most important pulse crops of India after chick pea. Among various biotic factors limiting pigeon pea yield, weeds are of prime importance which can causes seed yield losses up to 80 per cent. Therefore, weed management is an important key factor for enhancing the productivity of pigeon pea. Imazethapyr, an herbicide of imidazolinones group has been registered for soybean, groundnut and other legumes. Various trials in different regions were conducted to study the effects of imazethapyr alone or in combination for controlling the weeds in different crops but in pigeon pea limited research were conducted. Therefore, current study aimed to study the effect of imidazolinones alone and in combination on weed dry matter accumulation in pigeon pea (*Cajanus cajan* L.).

Methods: Pre and post emergence application of imidazolinones alone and in combination was done and dry matter accumulation by different types of weeds i.e. grassy, broad leaf and sedges in pigeon pea crop were worked out at different interval of crop span.

Result: Among all weed controls treatments, two hoeing at 40 and 70 DAS found most effective to control all kind of weeds. Alone application of pendimethalin was not effective to control sedges. PRE application of imidazolinones was comparatively more effective than POE application. Application of imidazolinones in combination with pendimethalin improves its efficacy to control total weeds than alone application of it. Therefore, PRE application of pendimethalin + imazethapyr @ 1000 + 75 g ha^{-1} proved to be an effective and a profitable alternative to the existing recommendation (two hoeing at 25 and 45 DAS) of weed control in pigeon pea in Haryana locality.

Key words: Dry matter accumulation, Imidazolinones, Pendimethalin + Imazethapyr, Pigeonpea, Weeds.

INTRODUCTION

Pulses are considered as the most important food crops after cereals which are not only the major source of dietary protein for vegetarian population of the world but also supply 20 per cent of dietary calories too. By virtue of its high protein content (20-25%) which is double the protein content of wheat and three times that of rice, pulses can be a viable option to overcome nutritional insecurity. India is world largest pulse producing and consuming country contributing one-third (35.6%) of total global area and one-fourth (27.8%) of total global production under pulses. In spite of being largest producer, India is lagging behind to produce enough to maintain the pace of population growth and to meet its domestic requirement It has to import two million tonnes of pulses every year by spending huge amount of foreign exchange (Chaturvedi and Ali, 2002). In India, the area under pulses is 29.8 million hectares with a production of 25.4 million tonnes and productivity of 853 kg ha^{-1} during 2016-17 (Anonymous, 2020a). The per capita availability of pulses has dwindled down from 60 g $capita^{-1}$ day^{-1} in 1951 to 54.5g $capita^{-1}$ day^{-1} in 2018 as against World Health Organization recommendation of 80 g $capita^{-1}$ day^{-1} (Anonymous, 2020b). Thus, there is an urgent need to increase the production to meet the increasing demand by improving the production technologies appropriately.

Among pulse crops, pigeon pea [*Cajanus cajan* (L.) Millsp] is one of the most important pulse crop of India after chick pea. It is used for food, feed and fuel. Pigeon pea also known as Arhar, Red gram, Tur, No eye pea, Gungopea and Congopea (Prasad *et al*., 2006) belongs to genus *Cajanus* and species *cajan* under family leguminosae. India has a virtual monopoly in pigeon pea production accounting 67.3 per cent of world's total production from 79.7 per cent of world's total area under pigeon pea. Myanmar, Malawi, Kenya, Tanzania, Haiti and Uganda are the other major pigeon pea producing countries of the world. In India, it occupies an area of 4.44 million hectares and production of 4.29 million tonnes with an average productivity of 967 kg ha^{-1} during 2017-18 (Anonymous, 2020c). It is grown mainly in Maharashtra, Madhya Pradesh, Karnataka, Uttar Pradesh, Gujarat and Andhra Pradesh. In Haryana, pigeon pea was cultivated over an area of 4.10 thousand hectares with an

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annual production of 4.50 thousand tonnes and productivity of 1067 kg ha^{-1} in 2017-18 (Anonymous, 2020c).

Pigeon pea is a short-lived perennial shrub and it is traditionally cultivated in rainy season (*kharif*) in month of June-July under assured rainfall conditions in India. Maturity period of pigeon pea varies from about 90 days to more than 260 days depending upon varieties. Among various biotic factors limiting pigeon pea yield, weeds are of prime importance which can causes seed yield losses up to 80 per cent (Talnikar *et al*., 2008). Rainy season, slow initial growth and sowing at wider spacing of pigeon pea encourage rapid growth and severe infestation of weeds. Hence, initial period of 6-8 weeks of pigeon pea are critical in terms of crop weed competition, which may eventually reduce the seed yield (Channappagoudar and Biradar, 2007). Moreover, besides low yield of crop, weeds increase production cost, hosts insect-pest and diseases, decreases quality of produce, reduce land value leading to reduction in crop production (Subramainian *et al*., 1993). Therefore, weed management is an important key factor for enhancing the productivity of pigeon pea. Weeds in pigeon pea can be controlled effectively with hand weeding twice at 3 and 6 weeks after sowing of crops. But due to frequent rains it becomes difficult to do hand weeding at proper time. Further non-availability and high cost of labour for hand weeding is another problem. Manual and mechanical methods of weed control are quite effective, but they are costly and time consuming (Ram *et al*., 2011). So there is a need to find out effective weed control technique using herbicides. Herbicides usage is now gaining importance in Indian agriculture.

In pigeon pea, to control weeds effectively many herbicides have been recommended as pre emergence such as fluchloralin, linuron, quizalofop, imazethapyr (Kaur *et al*., 2015), alachlore (Pardeshi *et al*., 2008), metolachlor (Nagaraju and Kumar, 2009) and pendimethalin (Singh *et al*., 2010). Imazethapyr, an herbicide of imidazolinones group has been registered for soybean, groundnut and other legumes (Herbicides Handbook, 2002). Imazethapyr is applied as pre-plant incorporated, pre-emergence and post-emergence to control grasses and broad leaved weeds in pulses crops. Various trials in different regions were conducted to study the effects of imazethapyr alone or in combination for controlling the weeds in different crops. Mishra *et al.* (2001) found that Imazethapyr (75 g ha^{-1}) gave an effective control of grassy as well as broad leaved weeds in soybean. Application of imazethapyr + pendimethalin (RM) @ 900 g ha^{-1} pre emergence effectively controls the weeds in green gram. Also promising results of post emergence application of imazethapyr + imazamox was observed in green gram @ 70g ha^{-1} (Singh *et al*., 2018). In spite of controlling the weeds effectively, extensive and under injudicious application of herbicides, most of the unused fractions of herbicides may persist within soils (Madhaiyan *et al*., 2006).

Therefore, taking into consideration above facts the present field experiment was conducted during 2017-18 and 2018-19 to study the effect of different weed control treatments on dry matter accumulation by grassy, broad leaf, sedges and to total weeds.

MATERIALS AND METHODS

The present field experiment was conducted at Agronomy Research Farm, CCS Haryana Agricultural University, Hisar, India during 2017-18 and 2018-19. Geographically, Hisar is situated at 29° 10′N latitude, 75° 46′E longitude and at an altitude of 215.2 meters above mean sea level. The climate of Hisar is semi-arid characterized by hot and dry summer and severe cold during winter season. Texture of the soil of experimental field was sandy-loam and it is slightly alkaline in reaction. The fertility status of soil was medium in organic carbon, medium in available nitrogen and phosphorus but high in available potassium. The experiment was laid out in randomized block design using eighteen treatment combinations *viz*., T_1- imazethapyr @ 75 g ha^{-1} as PRE, T_2- imazethapyr @ 100 g ha^{-1} as PRE, T_3- imazethapyr @ 75 g ha^{-1} at 45 DAS, T_4- imazethapyr @ 100 g ha^{-1} at 45 DAS, T_5- imazethapyr + imazamox @ 70 g ha^{-1} as PRE, T_6- imazethapyr + imazamox @ 100 g ha^{-1} as PRE, T_7- imazethapyr + imazamox @ 70 g ha^{-1} at 45 DAS, T_8- imazethapyr + imazamox @ 100 g ha^{-1} at 45 DAS, T_9- pendimethalin + imazethapyr @ 750 + 50 g ha^{-1} as PRE, T_{10}- pendimethalin + imazethapyr @ 1000 + 50 g ha^{-1} as PRE, T_{11}- pendimethalin + imazethapyr @ 750 + 65 g ha^{-1} as PRE, T_{12}- pendimethalin + imazethapyr @ 1000 + 65 g ha^{-1} as PRE, T_{13}- pendimethalin + imazethapyr @ 750 +75 g ha^{-1} as PRE, T_{14}- pendimethalin + imazethapyr @ 1000 + 75 g ha^{-1} as PRE, T_{15}- pendimethalin @ 1000 g ha^{-1} as PRE, T_{16}- weed free, T_{17}- weedy check and T_{18}- two hoeings at 40 and 70 DAS, replicated thrice. The experimental field was properly prepared in the first week of June during both the years. Field was ploughed twice with tractor drawn cultivator after harvest of the previous crop to crush clods. A uniform basal dose of 20 kg nitrogen and 40 kg phosphorus ha^{-1} was applied through Urea and DAP, at the time of field preparation. On well prepared field, seeds of the pigeon pea crop variety 'Paras' @ 15 kg ha^{-1} were sown by seed cum fertilizers drill. All agronomic practices as per recommendation of CCS HAU, Hisar were followed irrespective of the treatments.

In pigeon pea crop, imazethapyr, imazethapyr + imazamox (RM), pendimethalin + imazethapyr and pendimethalin were applied as pre emergence (PRE) spray to the soil surface as per treatment on the day of sowing and, imazethapyr, imazethapyr + imazamox (RM) were applied as post emergence (POE) at 45 DAS. Herbicides were applied with the aid of manually operated powered with 12V chargeable battery of 16 liters tank capacity 'V-dyut Delux a product of ASPEE' knapsack sprayer fitted with flat fan nozzle using 600 liters of water per hectare for precise and uniform application of herbicides and sufficient moisture was maintained in the soil at the time of application.

The associated weeds which were collected with the help of 0.25 square meter quadrat at 30, 60, 90, 120 DAS

and at harvest were removed species wise from two places in each plot. These samples of individual weed species were kept in paper bags or wrap into used newspaper and first sun dried and thereafter dried in oven at 65±5°C till constant weight achieved. Then dried weed samples were weighed and the dry weight of different grassy, broad leaf, sedges and total weeds were expresses in g m^{-2}. Later, the original data were subject to square root transformation before statistical analysis. The data obtained on various observations were tabulated and subjected to statistical analysis by using the techniques of the analysis of variance (ANOVA) as suggested by Panse and Sukhatme (1967). Analysis were performed in 'The SAS System 9.3'. In graph error bar with standard deviation is presented.

RESULTS AND DISCUSSION

Experimental field was infested with different kind of weeds such as *Echinochloa colona*, *Cynodon dactylon*, *Dactyloctenium aegyptium* and *Digitaria sanguinalis* among grassy weeds; *Trianthema portulacastrum* and *Digera arvensis* among BLWs and *Cyperus rotundus* in sedges. Among all weed controls treatments, two hoeings done at 40 and 70 DAS was found most effective to control all kind of weeds. PRE application of pendimethalin + imazethapyr @ 1000 + 75 g ha^{-1} provided acceptable level of control of total weeds.

Dry matter accumulation by grassy weeds

The perusal of pooled data of two years presented in Table 1 revealed that all the weed control treatments significantly reduced the dry matter accumulation by grassy weeds over weedy check. With the growing season of pigeon pea infestation of grassy weed in field increased up to 120 DAS. At every time of observation taken except at 30 DAS (upto when hoeing was not employed), significantly lowest dry matter accumulation by grassy weeds was observed in T_{18} (where two hoeings at 40 and 70 DAS were employed) which gave statistically at par control of grassy weeds as observed in weed free condition (T_{16}). Employment of two hoeings reduced the biomass accumulation of grassy weeds by 93.5-99.2 per cent throughout the crop growing season. While comparing the herbicides treatments, comparatively highest control of grassy weeds was observed in treatments where imidazolinones combined with pendimethalin than alone application of imidazolinones. But PRE application of imidazolinones provided significantly better control of grassy weed than POE application of it at their respective dose (either lower or upper). No herbicides were able to control the dry matter accumulation by grassy weeds enough as controlled in weed free condition or as in two hoeings condition employed at 40 and 70 DAS. Treatment T_{14} (PRE application of pendimethalin + imazethapyr @ 1000 + 75 g ha^{-1}) controlled the grassy weed biomass by 80.0-91.5 per cent which gave statistically at par results with treatment T_{13} (PRE application of pendimethalin + imazethapyr @ 750 + 75 g ha^{-1}) at every stage of observation taken. These results are in agreemnet with findings of Kaur *et al*., 2016 who found total control of grassy weeds. At later stages (90 and 120 DAS), alone PRE application of imazethapyr at 100g ha^{-1} (upper dose) alone gave same results in terms of grassy weed biomass control as obtained from treatments of imidazolinones combination with pendimethalin (T_9-T_{14}).

Table 1: Effect of different treatments on dry matter accumulation by grassy weeds in pigeon pea. (Pooled data of two years).

Treatments	Dry matter accumulation by grassy weeds				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1	3.33^{cb} (10.2)	6.14^{fhg} (37.1)	7.22^{ed} (52.1)	7.92^{dfe} (62.5)	7.36^{de} (54)
T_2	2.4^{ef} (4.8)	4.82^{jik} (22.4)	6.07^{ef} (36)	6.97^{gfe} (48.1)	6.73^{def} (44.8)
T_3	6.99^{a} (47.9)	8.83^{b} (77.1)	10.82^{b} (116.4)	11.82^{b} (140.5)	11.01^{ba} (123.2)
T_4	7.07^{a} (49)	7.8^{cbd} (59.9)	9.14^{c} (82.7)	10.84^{bc} (117.2)	9.64^{bc} (92.6)
T_5	3.68^{b} (12.6)	6.66^{fed} (43.5)	7.85^{d} (61.3)	8.84^{dce} (77.2)	8.11^{dc} (65.1)
T_6	2.79^{ed} (6.8)	5.27^{jihg} (27.1)	6.79^{ed} (46.3)	7.69^{dfe} (58.5)	7.32^{de} (54.1)
T_7	6.97^{a} (47.7)	8.47^{cb} (70.8)	10.47^{b} (109.4)	12.03^{ba} (144.4)	11.03^{ba} (120.8)
T_8	6.94^{a} (47.3)	7.38^{ced} (53.6)	9.21^{c} (85.1)	10.5^{bc} (109.7)	10.25^{ba} (105.3)
T_9	3.04^{cd} (8.5)	5.48^{fihg} (29.6)	6.78^{ed} (45.7)	7.41^{dfe} (55.1)	7.27^{de} (53.6)
T_{10}	2.41^{ef} (5)	5.31^{jihg} (28)	6.45^{ef} (41.3)	6.86^{gfe} (46.2)	7.01^{def} (50.5)
T_{11}	2.43^{ef} (4.9)	4.94^{jih} (23.5)	6.29^{ef} (39)	6.71^{gf} (44.3)	6.83^{def} (46)
T_{12}	2.19^{gf} (3.8)	4.56^{jik} (20.1)	6.13^{ef} (36.6)	6.94^{gfe} (47.6)	7.02^{def} (48.9)
T_{13}	2.03^{gf} (3.2)	4.24^{jk} (17.2)	5.35^{gf} (28.2)	6.26^{gf} (39)	6.27^{ef} (38.8)
T_{14}	1.86^{g} (2.5)	3.67^{k} (12.6)	4.68^{g} (20.9)	5.28^{g} (28.9)	5.55^{f} (30.1)
T_{15}	2.75^{ed} (6.6)	6.18^{feg} (38.4)	7.18^{ed} (52)	9.28^{dc} (86.3)	9.55^{bc} (90.2)
T_{16}	1^{h} (0)	1^{l} (0)	1^{h} (0)	1^{h} (0)	1^{h} (0)
T_{17}	6.92^{a} (47.4)	12.1^{a} (148.4)	13.84^{a} (190.9)	14.03^{a} (205.7)	11.64^{a} (136.5)
T_{18}	7.04^{a} (48.5)	1.48^{l} (1.2)	1.89^{h} (2.6)	2.68^{h} (6.8)	3.01^{g} (8.9)

Original data given in parenthesis were subjected to square root $\sqrt{X+1}$ transformation before analysis; Value with atleast one letter common are not significantly different.

Table 2: Effect of different treatments on dry matter accumulation by broad leaf weeds in pigeon pea. (Pooled data of two years).

Treatments	Dry matter accumulation by broad leaf weeds (g m^{-2})				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1	2.56^{dc} (5.6)	4.19^{ed} (16.7)	5.23^{ed} (26.4)	4.42^{bac} (24.8)	3.29^{bedc} (20.4)
T_2	1.97^{gf} (2.9)	3.53^{efg} (11.5)	4.46^{egf} (18.9)	2.74^{bc} (12.6)	2.65^{bedc} (11.4)
T_3	5.97^{a} (34.8)	6.23^{cb} (37.9)	7.81^{b} (60.2)	7.04^{ba} (51.5)	6.12^{bac} (37.3)
T_4	5.94^{a} (34.5)	5.63^{c} (30.7)	7.09^{cb} (49.5)	4.79^{bac} (37.9)	5.32^{bedc} (38.9)
T_5	2.78^{c} (6.7)	4.64^{d} (20.6)	5.64^{d} (31)	4.17^{bac} (24.3)	3.92^{bedc} (21.4)
T_6	2.21^{dfe} (3.9)	3.82^{ef} (13.6)	4.92^{edf} (23.4)	3.35^{bc} (21.2)	3.33^{bedc} (13.3)
T_7	5.96^{a} (34.5)	6.18^{cb} (37.2)	7.66^{cb} (58.1)	4.81^{bac} (38.9)	6.7^{ba} (50.2)
T_8	5.95^{a} (34.5)	5.61^{c} (30.7)	6.89^{c} (47.2)	6.26^{bac} (41.9)	4.9^{bedc} (33.7)
T_9	2.44^{dce} (5.1)	3.77^{ef} (13.3)	4.9E^{df} (23.3)	4.29^{bac} (26.7)	3.86^{bedc} (18.8)
T_{10}	2.3^{dfe} (4.4)	3.6^{efg} (12)	4.56^{ef} (19.8)	3.92^{bac} (20.8)	2.41^{bedc} (8.7)
T_{11}	2.06^{gfe} (3.3)	3.34^{fg} (10.3)	4.43^{egf} (18.9)	3.93^{bac} (19.7)	3.27^{bedc} (12.7)
T_{12}	2.07^{gfe} (3.5)	2.99^{hg} (8.1)	4.27^{gf} (17.3)	2.75^{bc} (12.7)	1^{e} (0)
T_{13}	1.68^{g} (2)	2.33^{ih} (4.5)	3.6^{g} (12.3)	2.58^{bc} (10.7)	2.08^{edc} (5.7)
T_{14}	1.22^{h} (0.6)	1.8^{ij} (2.3)	2.49^{h} (5.6)	1^{c} (0)	1^{e} (0)
T_{15}	4.57^{b} (19.9)	6.36^{b} (39.7)	7.95^{b} (63.5)	5.43^{bac} (47.9)	5.57^{bdc} (34.1)
T_{16}	1^{h} (0)	1^{k} (0)	1^{i} (0)	1^{c} (0)	1^{e} (0)
T_{17}	6.18^{a} (37.5)	8.79^{a} (77.4)	10.52^{a} (109.8)	9.47^{a} (115.1)	10.37^{a} (117)
T_{18}	6.04^{a} (35.6)	1.49^{kj} (1.3)	1.98^{h} (3)	1.44^{bc} (1.5)	1.58^{ed} (2.1)

Original data given in parenthesis were subjected to square root $\sqrt{X+1}$ transformation before analysis; Value with atleast one letter common are not significantly different.

It may be due to the leaching of it below the root zone making the soil active with time. Similarly Alister and Kogan, (2005) also reported that imazapyr/imazapic mixture was found to be most persistent herbicide that remains in soil active (carry over effect) over 10 months after application. Weedy check treatment (T_{17}) accumulated highest biomass (205.7 g m^{-2} at 120 DAS) of grassy weeds obviously as no weed management practice was employed and weeds are allowed to grow freely.

Dry matter accumulation by broad leaf weeds (BLWs)

Pooled data of two years study regarding dry matter accumulation by broad leaf weeds (BLWs) presented in Table 2 showed that all the weed control treatments significantly reduced the dry matter accumulation by broad leaf weeds over weedy check. With the pursuing of growing season of pigeon pea infestation of BLWs in field increased upto 90 DAS and thereafter due to ageing of BLWs infestation reduced. At every time of observation taken except at 30 DAS upto when hoeing was not employed), significantly lowest dry matter accumulation by BLWs was observed in T_{18} (where two hoeings at 40 and 70 DAS were employed) which gave statistically at par control of BLWs as observed in weed free condition (T_{16}). Employment of two hoeings reduced the BLWs biomass accumulation by 95.7-98.9 per cent throughout the crop growing season. While comparing the herbicides treatments, comparatively higher control of BLWs was observed in treatments where imidazolinones combined with pendimethalin than alone application of imidazolinones. But PRE application of imidazolinones provided significantly better control of BLWs than POE application of it at their respective dose (either lower or higher). Treatment T_{14} (PRE application of pendimethalin + imazethapyr @ 1000 + 75 g ha^{-1}) controlled the BLWs biomass by 88.0-93.5 per cent which gave statistically at par results with treatment T_{18} (Two hoeing at 40 and 70 DAS) at every stage of observation taken. At later stages (120 DAS and at harvest) it was found that all the PRE application of imidazolinones alone or in combination with pendimethalin at either dose significantly reduced the broad leaf weed biomass and gave statistically same control as obtained in weed free plot. And POE application of imazethapyr at 100 g ha^{-1} (upper dose) and its combination with imazamox either at 70 or 100 g ha^{-1} significantly controlled BLWs biomass and gave statistically at par results in tune with weed free plot. Weedy check treatment (T_{17}) accumulated highest biomass (205.7 g m^{-2} at 120 DAS) of grassy weeds obviously as no weed management practice were employed and weeds were allowed to grow freely.

Dry matter accumulation by sedges

Pooled data of two years of dry matter accumulation by sedges is presented in Table 3 indicated that all the weed controls treatments significantly reduced the dry matter accumulation by sedges over weedy check except PRE application of pendimethalin alone at 1000 g ha^{-1}. With span of growing season of pigeon pea infestation of sedges in field increased. Obviously no sedge was found in weed free condition. Treatments T_{18} (Two hoeings at 40 and 70 DAS) and T_{14} (PRE application of pendimethalin + imazethapyr @ 1000 + 75 g ha^{-1}) gave statistically at par control of dry matter accumulation by sedges as observed in weed free condition.

Table 3: Effect of different treatments on dry matter accumulation by sedges in pigeon pea. (Pooled data of two years).

Treatments	Dry matter accumulation by sedges (g m^{-2})				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1	1.12^{cbd} (0.3)	1.41^{dce} (1)	1.9^{cd} (2.6)	2.35^{b} (4.6)	2.42^{ced} (4.9)
T_2	1.08^{ced} (0.2)	1.31^{dfge} (0.7)	1.66^{ef} (1.8)	1.81^{ced} (2.3)	1.78^{fe} (2.2)
T_3	1.57^{a} (1.5)	1.82^{b} (2.3)	2.09^{cb} (3.4)	2.34^{b} (4.5)	2.95^{cb} (7.8)
T_4	1.56^{a} (1.4)	1.57^{c} (1.5)	2.06^{cb} (3.2)	2.35^{b} (4.5)	2.25^{ced} (4.1)
T_5	1.2^{b} (0.4)	1.5^{dc} (1.2)	2^{cb} (3)	2.07^{cbd} (3.3)	2.43^{ced} (5.2)
T_6	1.15^{cb} (0.3)	1.34^{dfce} (0.8)	1.74^{ed} (2)	1.94^{cebd} (2.8)	2.04^{ed} (3.2)
T_7	1.55^{a} (1.4)	1.82^{b} (2.3)	2.08^{cb} (3.3)	2.23^{cb} (4)	3.32^{b} (10.1)
T_8	1.53^{a} (1.3)	1.55^{c} (1.4)	2.17^{b} (3.7)	2.2^{cb} (3.8)	2.76^{cbd} (6.6)
T_9	1.12^{cbd} (0.3)	1.34^{dfce} (0.8)	1.74^{ed} (2)	1.84^{ced} (2.4)	2.22^{ced} (4)
T_{10}	1.12^{cbd} (0.3)	1.3^{dfge} (0.7)	1.65^{ef} (1.7)	1.84^{ced} (2.4)	2.18^{ed} (3.8)
T_{11}	1.11^{cbd} (0.2)	1.28^{dfge} (0.6)	1.63^{ef} (1.7)	1.72^{ed} (2)	2^{fe} (3.1)
T_{12}	1.07^{ced} (0.2)	1.2^{hfge} (0.4)	1.58^{ef} (1.5)	1.67^{ed} (1.8)	1.97^{fe} (2.9)
T_{13}	1.04^{ed} (0.1)	1.17^{hfg} (0.4)	1.47^{gf} (1.2)	1.56^{ef} (1.5)	1.93^{fe} (2.7)
T_{14}	1.03^{ed} (0.1)	1.09^{hg} (0.2)	1.3^{gh} (0.7)	1.55^{ef} (1.4)	1.81^{fe} (2.3)
T_{15}	1.58^{a} (1.5)	2.3^{a} (4.4)	3.22^{a} (9.5)	3.67^{a} (12.9)	4.1^{a} (16.4)
T_{16}	1^{e} (0)	1^{h} (0)	1^{i} (0)	1^{g} (0)	1^{g} (0)
T_{17}	1.58^{a} (1.5)	2.33^{a} (4.5)	3.25^{a} (9.6)	3.9^{a} (14.5)	4.09^{a} (16.7)
T_{18}	1.55^{a} (1.4)	1.02^{h} (0)	1.11^{ih} (0.2)	1.15^{gf} (0.3)	1.3^{fg} (0.7)

Original data given in parenthesis were subjected to square root $\sqrt{X+1}$ transformation before analysis; Value with atleast one letter common are not significantly different.

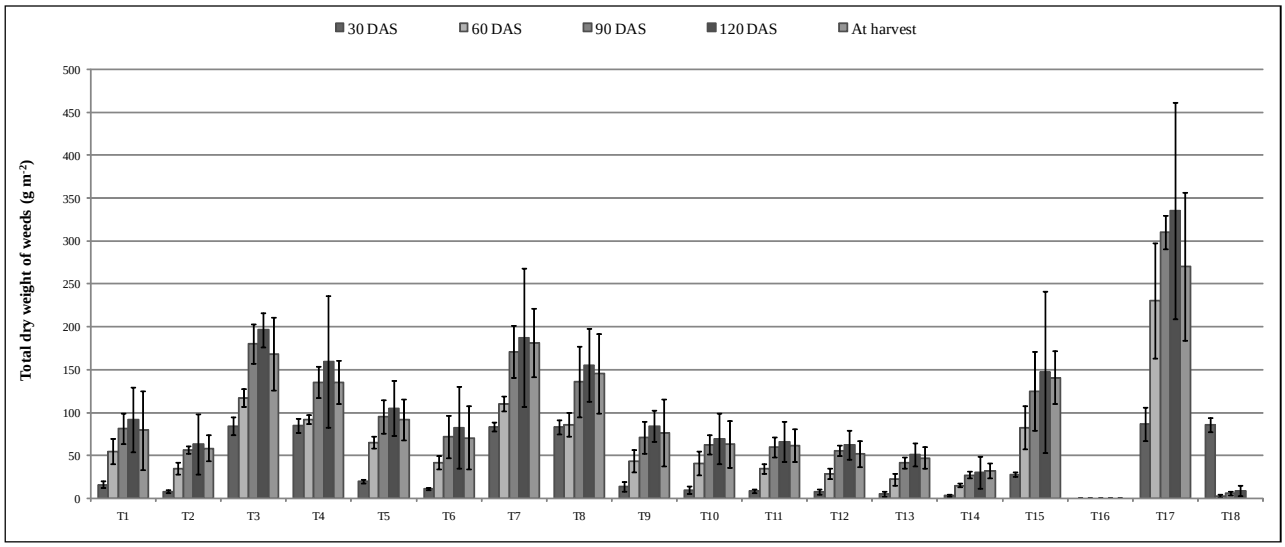


Fig 1: Effect of Imidazolinones alone and in combination on total weed biomass in pigeon pea at different crop span (pooled data of two years).

Dry matter accumulation by total weed

Pooled analysis of two years on the effect of different weed control treatments on total weeds dry matter accumulation is presented in Fig 1 which depicted that significantly lowest total weed dry matter accumulation was observed in T_{18} (Two hoeings at 40 and 70 DAS) which gave almost weed free condition. Total weed biomass increased upto 120 DAS and thereafter decreased due to ageing. POE application of imidazolinones was less effective in controlling the weeds in comparison to PRE herbicides of imidazolinones at similar doses because after crossing 45 DAS stage herbicides were no longer much effective to suppress the weeds present at the time of application. Higher dose of imidazolinones was more effective in controlling the total weeds than their lower doses. Among all the herbicides treatments, PRE application of imidazolinones in combination with pendimethalin (T_9-T_{14}) was found comparatively more effective to control total weed dry weight than PRE application of imidazolinones alone. It may be due to the reason that these herbicides combination suppress the growth of weeds and did not

allow the future flush of weeds to emerge. Among different herbicides used in study, PRE application of pendimethalin + imazethapyr @ 1000 + 75 g ha^{-1} (T_{14}) reported significantly lowest total dry matter accumulation by weeds which was statistically at par with PRE application of pendimethalin + imazethapyr @ 750 + 75 g ha^{-1} (T_{13}) at all the times of crop growth. Similar results were obtained by Gupta *et al*. (2017) and Chavan*et al*. (2018). Higher weed control efficiency in T_{14} (pendimethalin + imazethapyr @ 1000 + 75 g ha^{-1}) and per cent control of weeds may also be attributed to root and shoot inhibiting action of pendimethalin on weeds (Appleby and Valverde, 1988 and Gilliam *et al.,* 1993) and at later stages due to the higher persistence of imazethapyr as half life of imazethapyr varies from 78-270 days (Goetz *et al.,* 1990).

CONCLUSION

Keeping the field weed free *via* hoeing is laborious, time consuming and costlier weed management practice. In pigeon pea which is a rainy season crop in Haryana it is not possible to employ hoeing in rainy condition. Application of pendimethalin alone is not found effective to control sedges. All herbicide treatments except pendimethalin provided acceptable level of control but combination of imidazolinones with pendimethalin controls the total weeds significantly. Therefore, PRE application of pendimethalin + imazethapyr @ 1000 + 75 g ha^{-1} proved to be an effective and a profitable alternative to the existing recommendation (two hoeing at 25 and 45 DAS) of weed control in pigeon pea in Haryana.

REFERENCES

Anonymous. (2020a). Ministry of Agriculture and Farmers Welfare, Govt. of India. (ON2271) and Past Issues. https://www.indiastat.com/table/agriculture-data/2/agricultural-production/225/7270/data.aspx.

Anonymous. (2020b). Ministry of Agriculture, Govt. of India.(14268), (ON463), (ON810). https://www.indiastat.com/table/per-capita-availability-data/24/food-items/103/6368/data.aspx.

Anonymous. (2020c). Ministry of Agriculture and Farmers Welfare, Govt. of India. (ON2271) and Past Issues. https://www.indiastat.com/table/agriculture-data/2/arhar-tur/19566/1229701/data.aspx.

Appleby, J.R. and Valverde, B.E. (1988). Behavior of dinitroaniline herbicides in plants. Weed Technology. 3: 198-206.

Channappagoudar, B.B. and Biradar, N.R. (2007). Physiological approaches for weed management in soybean and red gram intercropping system. Karnataka Journal of Agricultural Science. 20(2): 241–244.

Chaturvedi, S.K. and Ali, M. (2002). “Poor man’s meat” needs fresh fillip. The Hindu Survey of Indian Agriculture, pp: 63-69.

Chavan, A.S., Raj, V.C. and Waghmare, P.K. (2018). Residues studies of Pendimethalin and other herbicides in pigeon pea field through bioassay technique. International Journal of Current Microbiology and Applied Sciences. 6 (Special Issue): 1866-1873.

Gilliam, C.H., Eakes, D.J. and Olive, J.W. (1993). Herbicide use during propagation affects root initiation and development. Journal of Environmental Horticulture. 11: 157-159.

Goetz, A.J., Lavy, T.L. and Gbur, E.E. (1990). Degradation and field persistence of imazethapyr. Weed Science. 38: 421-428.

Gupta, V., Sasode, D.S., Kansana, B.S., Arora, A., Dixit, J. P. and Joshi, E. (2017). Weed management with pre and post-emergence herbicides in black gram. Indian Journal of Weed Science. 49(3): 256-259.

Herbicide Handbook. (2002). Imazethapyr. WSSA Herbicide Handbook - 8th Edition, pp: 256-258.

Kaur, R., Raj, R., Das, T.K., Shekhawat, K., Singh, R. and Choudhary, A.K. (2015). Weed management in pigeon pea based cropping systems. Indian Journal of Weed Science. 47(3): 267-276.

Kaur, S., Kaur, T. and Bhullar, M.S. (2016).Imidazolinone herbicides for weed control in greengram. Indian Journal of Weed Science. 48(1): 37-39.

Madhaiyan, M., Poonguzhali, S., Hari, K., Saravanan, V.S. and Sa, T. (2006). Influence of pesticides on the growth rate and plant growth promoting traits of *Gluconacetobacter diazotrophicus*. Pesticide Biochemistry and Physiology. 84: 143-154.

Mishra, O.R., Gautam, V.S., Dinesh, E., Rajput, A.M. and Patidar, G.L. (2001). Integrated weed management and its economics in soybean. Crop Research. 21(1): 115-119.

Nagaraju, A.P. and Kumar, H.M. (2009). Efficacy of herbicides on weed control in pigeon pea [*Cajanus cajan* (L.) Millsp]. Mysore Journal of Agricultural Sciences. 43(2): 201-204.

Panse V.G. and Sukhatme, P.V. (1967). Statistical Methods for Agricultural Workers, ICAR, Publication New Delhi.

Pardeshi, S.S., Paturde, J.T., Kagne, S.V., Chavan, P.G., Dhale, S.A. and Raut, V.S. (2008). Effect of weed management practices on weed growth and seed yield of maize + pigeon pea intercropping system. Journal of Soils and Crops. 18(2): 454-457.

Prasad, R., Ahlawat, I.P.S. and Shivakumar, B.G. (2006). Textbook of Field Crops Production. Publication of Agricultural Research Krishi Anusandhan Bhavan, New Delhi-110 012.

Ram, B., Punia, S.S., Meena, D.S. and Tetarwal, J.P. (2011). Bioefficacy of post-emergence herbicides to manage weeds in field pea. Journal of Food Legumes. 24: 254-257.

Singh, G., Aggarwal, N. and Ram, H. (2010). Effect of row spacing and weed management practices on weeds, growth and yield of pigeon pea [*Cajanus cajan* (L.) Millsp.]. Indian Journal of Weed Science. 42(3 and 4): 241-243.

Singh, S.P., Yadav, R.S., Kumawat, A. and Bairwa, R.C. (2018). Weed control in green gram (*Vigna radiata*) and its residual effect on Indian mustard (*Brassica juncea*). Indian Society of Agronomy. 63: 21-25.

Subramanian, S. Mohamed, A. and Jayakumar, R. (1993). All About Weed Control. Kalyani Pub., New Delhi. pp: 1-5.

Talnikar, A.S., Kadam, G.L., Karande, D.R. and Jogdand, P.B. (2008). Integrated weed management in pigeon pea [*Cajanus cajan* (L.) Millsp.]. International Journal of Agricultural Sciences. 4(1): 363-370.