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Influence of imidazolinones alone and in combination on pigeonpea (*Cajanus cajan*)

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ABSTRACT

A field experiment was conducted to study the influence of imidazolinones alone and in combination on pigeon pea [*Cajanus cajan* (L.) Millsp] at CCS Haryana Agricultural University, Hisar, India during 2017-18 and 2018-19. The experiment was laid out in randomized block design using 18 treatment combinations replicated thrice. During both the years, due to weed free condition, taller (272.3 cm) and heavier (200.1 g) plant at harvest, higher yield attributes (11.5 plants/m^2 at harvest; 92.8 pods/plant; 3.30 seeds/pod and 7.22 g 100-seed weight) and productivity (1914, 6259 and 8172 kg/ha seed, stalk and biological yield, respectively and 23.4% harvest index) of pigeonpea was observed in weed free treatment which was closely followed by treatment where two hoeings at 40 and 70 DAS were employed. While comparing the different herbicides treatments, PRE application of pendimethalin + imazethapyr @ 1000 + 75 g/ha gave statistically at par productivity of pigeon peaas obtained in weed free condition. Therefore, PRE application of pendimethalin + imazethapyr @ 1000 + 75 g/ha proved to be an effective and a profitable alternative to the existing recommendation (two hoeings at 25 and 45 DAS) of weed control in pigeonpea in Haryana.

Key words: Growth, Imidazolinones, Pendimethalin + Imazethapyr, Pigeonpea , Productivity

Food security is must to feed the continuous increasing population but in addition 'nutritional security' has now become an emerging global issue which is haunting the researchers. Pulse crops are commonly known as poor man's meat (Reddy 2010). Pigeonpea [*Cajanus cajan* (L.) Millsp] is one of the most important pulse crops of India after chickpea 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. It is a good source of rich amino acids, vitamins and minerals. India has a virtual monopoly in pigeonpea production accounting 67.3% of world's total production from 79.7% of world's total area under pigeonpea. In India, it occupies an area of 5.34 million ha and production of 4.87 million tonnes with an average productivity of 913 kg/ha during 2016-17 (Anonymous 2018).

Among various biotic factors limiting pigeonpea yield, weeds are of prime importance which can cause seed yield losses up to 80% (Talnikar *et al.* 2008). Rainy season, slow initial growth and sowing at wider spacing of pigeonpea encourage rapid growth and severe infestation of weeds. Hence, initial period of 6-8 weeks of pigeonpea are critical in terms of crop weed competition, which may eventually reduce the seed yield (Channappagoudar and Biradar 2007). Manual and mechanical methods of weed control are quite effective, but they are costly and time consuming (Ram *et al.* 2011). Also due to frequent rains it becomes difficult to do hand weeding at proper time in pigeonpea.

Herbicides of imidazolinones group are applied to control grasses and broad leaved weeds in pulses crops. Application of imazethapyr + pendimethalin (RM) @ 900 g/ha pre emergence effectively controls the weeds in green-gram. Also promising results of post emergence application of imazethapyr + imazamox was observed in greengram @ 70 g/ha (Singh *et al.* 2018).

Therefore, taking into consideration all the above facts, the present field experiment was conducted to study the influence of imidazolinones alone and in combination on pigeonpea.

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 29º 10´N latitude, 75º 46´E longitude and at an altitude of 215.2 m amsl. 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

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nitrogen and phosphorus but high in available potassium. The experiment was laid out in randomized block design using 18 treatment combinations, *viz*. T_1- imazethapyr @ 75 g/ha as PRE, T_2- imazethapyr @ 100 g/ha as PRE, T_3- imazethapyr @ 75 g/ha at 45 DAS, T_4- imazethapyr @ 100 g/ha at 45 DAS, T_5- imazethapyr + imazamox @ 70 g/ha as PRE, T_6- imazethapyr + imazamox @ 100 g/ha as PRE, T_7- imazethapyr + imazamox @ 70 g/ha at 45 DAS, T_8- imazethapyr + imazamox @ 100 g/ha at 45 DAS, T_9- pendimethalin + imazethapyr @ 750 + 50 g/ha as PRE, T_{10}- pendimethalin + imazethapyr @ 1000 + 50 g/ha as PRE, T_{11}- pendimethalin + imazethapyr @ 750 + 65 g/ha as PRE, T_{12}- pendimethalin + imazethapyr @ 1000 + 65 g/ha as PRE, T_{13}- pendimethalin + imazethapyr @ 750 +75 g/ha as PRE, T_{14}- pendimethalin + imazethapyr @ 1000 + 75 g/ha as PRE, T_{15}- pendimethalin @ 1000 g/ha 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 per ha was applied through Urea and DAP, at the time of field preparation. On well prepared field, seeds of the pigeonpea crop variety Paras @ 15 kg/ha were sown by seed cum fertilizers drill. All agronomic practices as per recommendation of CCS HAU, Hisar were performed irrespective of the treatments.

In pigeonpea 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 manually operated powered with 12V chargeable battery of 16 l tank capacity 'V-dyut Delux a product of ASPEE' knapsack sprayer fitted with flat fan nozzle using 600 l of water per ha for precise and uniform application of herbicides and sufficient moisture was maintained in the soil at the time of application.

Three tagged plants from marked per meter row length from each plot were observed for recording plant height at 30, 60, 90, 120 days after sowing (DAS) and at harvest. The three plants were harvested from the second row on either side in each plot at 30, 60, 90,120 DAS and at harvest. Plants samples were sun dried and thereafter, these samples were dried in the oven at 65+5^{o}C temperature till constant weight was achieved. Initial and final plant population of crop plant was taken at 20 DAS and at harvest, from one meter running row length in four rows randomly selected in each plot and then averaged out. After this, plant population per meter square was determined for each plot. After harvesting, total number of pods of the three tagged plants in each plot was counted and the average number of pods per plant was calculated. After taking biological weight of one square meter harvested plot from each treatment, 15 pods five from each of three tagged plant were randomly picked up and threshed to record the total number of seeds in them and averaged out to record number of seeds/pod. After recording observation seeds were mixed backed to produce for seed yield calculation. A representative sample of seeds was taken out from the seed yield of each plot at the time of threshing and 100 seeds were counted to report 100-seed weight. Harvested plants of one square meter were sundried for at least two week and threshed manually by beating. Then, threshed seeds obtained from each plot after proper cleaning were weighed using electronic weighing machine to find seed yield and converted to express as kg/ha. Stalk yield was calculated by subtracting the seed yield from the biological weight of the respective plot and expressed in kg/ha. Harvest index was calculated according to the following formula: Harvest index (%) = Economic yield/Biological yield × 100.

The data obtained on various observations of both the years were tabulated and subjected to statistical analysis by 'The SAS System 9.3'.

RESULTS AND DISCUSSION

Among herbicides treatments, PRE alone application of pendimethalin, lower dose of imidazolinones (imazethapyr @ 75 g/ha and its combination with imazamox with 70 g/ha) and POE application of imidazolinones did not produce promising results as produced from PRE application of combination of imidazolinones with pendimethalin, especially from treatment T_{14} and T_{13}.

The details of pooled data of two years presented in Table 1 depicted that tallest plants (272.3 cm at harvest) of pigeonpea at every stage of observation taken was recorded in weed free treatment (T_{16}). While comparing the herbicides treatments, pre emergence (PRE) application of pendimethalin + imazethapyr @ 1000 + 75 g/ha (T_{14}) gave significantly taller plants (269.9 cm at harvest) over rest of the other herbicides treatment except T_{13} to which it was statistically at par and after 90 DAS. Treatment T_{14} (PRE application of pendimethalin + imazethapyr @ 1000 + 75 g/ha) and T_{18} (two hoeing at 40 and 70 DAS) produced statistically at par plants height of pigeonpea with weed free (T_{16}) plot at harvest. Obviously, significantly lowest plant height (159.2 cm at harvest) of pigeonpea was recorded in weedy check plot (T_{17}) throughout the growing season. Significant variation in plant height of pigeonpea existed due to the effect of different weed control treatments. Pigeon pea plant height reduced by 41.5 % at harvest in weedy check plot than weed free plot over. This may be due to the more intense crop weed competition was faced by crop plant of pigeonpea for space and light with weeds in weedy checked condition. The results are in agreement with Mundra and Maliwal (2012) and Gaud and Patil (2014), who also reported the taller plants in weed free treatment in comparison to weedy check treatment at harvesting stage.

The pooled data presented in Table 1 indicated that maximum dry matter accumulation per plant (200.1 g at harvest) of pigeonpea at every stage of observation taken was reported in weed free (T_{16}) treatment. Treatments

Table 1 Effect of imidazolinones alone and in combination on plant height and dry matter accumulation by pigeon pea (pooled data of two years)

Treatment	Plant height					Dry weight/plant				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1	52.2^{DE}	156.2^{F}	212.2^{G}	247.2^{C}	249.2^{E}	3.1^{DE}	26.7^{EFGHIJ}	93.9^{EFG}	157.9^{FG}	173.9^{EF}
T_2	56.0^{BC}	158.8^{DE}	215.18^{DEFG}	249.4^{BC}	253.3^{CD}	3.2^{BCD}	27.6^{CDEF}	94.8^{EFG}	162.6^{DEF}	181.7^{CD}
T_3	45.5^{G}	140.2^{J}	196.55^{J}	220.7^{H}	227.8^{I}	2.5^{FG}	24.8^{K}	86.5^{H}	142.2^{J}	149.8^{I}
T_4	45.3^{G}	143.3^{HI}	197.35^{J}	225.1^{FG}	231.3^{H}	2.5^{FG}	25.3^{IJK}	87.1^{H}	145.8^{HIJ}	155.1^{HI}
T_5	49.1^{EF}	152.3^{G}	208.6^{H}	237.6^{D}	241.9^{F}	3.1^{DE}	26.1^{FGHIJK}	91.7^{FGH}	151.6^{GH}	166.9^{FG}
T_6	54.3^{CD}	156.7^{EF}	212.4^{FG}	248.2^{BC}	249.2^{E}	3.1^{DE}	26.9^{DEFGHI}	94.2^{EFG}	158.9^{EF}	174.9^{DE}
T_7	45.9^{FG}	141.7^{IJ}	197.0^{J}	223.1^{GH}	231.0^{HI}	2.5^{FG}	25.4^{JK}	86.9^{H}	144.8^{IJ}	153.4^{HI}
T_8	46.4^{FG}	145.4^{H}	199.2^{IJ}	229.2^{EF}	232.2^{GH}	2.6^{F}	25.5^{HIJK}	88.3^{GH}	148.1^{HIJ}	158.2^{H}
T_9	55.0^{BCD}	156.9^{EF}	214.1^{EFG}	248.4^{BC}	250.2^{DE}	3.2^{CDE}	27.2^{DEFGH}	94.3^{EFG}	161.0^{EF}	177.8^{CDE}
T_{10}	55.3^{BCD}	157.5^{EF}	215.6^{DEF}	250.0^{BC}	252.5^{CD}	3.2^{BCDE}	27.2^{DEFG}	95.6^{DEF}	164.4^{DEF}	180.7^{CDE}
T_{11}	55.8^{BC}	160.0^{D}	215.8^{CDE}	250.8^{BC}	250.4^{DE}	3.2^{BCDE}	27.9^{BCDE}	96.0^{CDEF}	165.1^{DE}	179.8^{CDE}
T_{12}	56.7^{BC}	160.7^{D}	216.2^{CDE}	252.3^{B}	254.6^{C}	3.3^{BCD}	28.3^{BCDE}	98.2^{BCDE}	167.6^{CD}	183.2^{C}
T_{13}	57.2^{BC}	163.9^{C}	218.5^{BCD}	263.6^{A}	268.0^{B}	3.3^{BC}	28.5^{BCD}	102.1^{BCD}	173.8^{BC}	191.3^{B}
T_{14}	57.9^{B}	167.7^{B}	219.0^{BC}	265.3^{A}	269.9^{AB}	3.3^{B}	29.1^{BC}	102.3^{BC}	175.2^{B}	192.9^{B}
T_{15}	49.0^{EF}	151.6^{G}	201.3^{I}	230.0^{E}	235.1^{G}	3.0^{E}	25.7^{GHIJK}	89.1^{GH}	150.6^{HI}	165.5^{G}
T_{16}	61.7^{A}	170.5^{A}	222.7^{A}	267.3^{A}	272.3^{A}	3.6^{A}	31.3^{A}	111.2^{A}	181.8^{A}	200.1^{A}
T_{17}	44.9^{G}	120.9^{K}	148.2^{K}	154.7^{I}	159.2^{J}	2.4^{FG}	19.7^{L}	74.9^{I}	86.4^{K}	94.4^{J}
T_{18}	44.0^{G}	168.0^{B}	220.2^{AB}	266.6^{A}	270.7^{AB}	2.4^{G}	29.7^{AB}	103.2^{B}	176.2^{AB}	193.9^{AB}

Value with atleast one letter common are not significantly different

T_{14} (PRE application of pendimethalin + imazethapyr @ 1000 + 75 g/ha) produced statistically at par dry weight per plant (192.9 g at harvest) of pigeonpea with T_{18} (two hoeings at 40 and 70 DAS) at every stage of observation taken except at 30 DAS. Obviously, significantly lowest dry matter accumulation per plant (94.4 g at harvest) of pigeonpea was recorded in weedy check plot (T_{17}). Weed free treatment recorded higher dry matter accumulation by crop plants due to absence of crop weed competition, while the lowest crop dry weight was recorded in weedy check treatment as no control measures were adopted towards weed management and thus weeds dominated the crop weed competition leads to reduction in leaf area, branches per plant which was responsible for lowest dry matter accumulation by pigeonpea in weedy check treatment. Similar results were also reported by Kumar *et al.* (2015) and Chavan *et al.* (2016).

The perusal of pooled data of two years given in Table 2 showed that none of the weed control treatments significantly affected the number of plants/m^2 of pigeonpea at 20 DAS and at harvest. Although the maximum number of plants/m^2 of pigeonpea (11.6 at 20 DAS and 11.5 at harvest) were recorded in weed free plot (T_{16}). Significantly higher number of pods/plant (92.8) and number of seeds/pod (3.30) of pigeonpea were recorded in weed free plot (T_{16}) over other treatments except treatment T_{18} (two hoeings at 40 and 70 DAS) to which it was statistically at par. Among herbicides treatments, application of imazethapyr in combination with pendimethalin produced statistically at par with number of pods/plant of pigeon pea with T_{18} (two hoeings at 40 and 70 DAS) except T_9 and highest pods/plant (86.0) of pigeon pea were recorded in treatment T_{14} (PRE application of pendimethalin + imazethapyr @ 1000 + 75 g/ha). Treatment T_{14} produced statistically at par with seeds/pod of pigeonpea as produced from weed free condition (T_{16}) and two hoeings employed at 40 and 70 DAS (T_{18}). Different weed control treatments did not affect the size of seed of pigeonpea and non significantly bolder seed (7.22g/100-seed) of pigeon-pea was recorded in weed free plot (T_{16}) which was in tune with T_{18} and T_{14}. Treatment T_{16} gave significantly higher seed yield (1914 kg/ha) and biological yield (8172 kg/ha) of pigeonpea among different treatments, but statistically at par with T_{18} (1890 and 8083 kg/ha, respectively) and T_{14} (1873 and 8043 kg/ha, respectively). Significantly highest stalk yield (6259 kg/ha) of pigeonpea was obtained in weed free condition (T_{16}) over other treatments except T_{18} (6193 kg/ha), T_{14} (6170 kg/ha) and T_{13} (6145 kg/ha) to them it gave statistically at par with stalk yield. Highest harvest index was recorded in T_{16} and T_{18} (23.4% each) which was statistically at par with treatment T_{11}, T_{12}, T_{13} and T_{14} where combined PRE application of imazethapyr with pendimethalin was done.

Unchecked growth of weeds in weedy check suppresses the growth of crop plant and effectively competes with the crop throughout the growing season thus adversely affect the yield and yield attributes. A reduction of 67.5% in seed yield

Table 2 Effect of imidazolinones alone and in combination on yield attributes and productivity of pigeonpea (pooled data of two years)

Treatment	No. of plants/m^2		No. of pods/ plant	No. of seeds/pod	100-seed weight (g)	Yield (kg/ha)			Harvest Index (%)
	20 DAS	At harvest				Seed	Stalk	Biological	
T_1	11.4	11.2	77.6^{DEFG}	3.18^{BCD}	7.14	1711^{E}	5845^{F}	7556^{D}	22.6^{DEFG}
T_2	11.3	11.2	79.3^{CDEF}	3.19^{BCD}	7.16	1776^{D}	5997^{E}	7773^{C}	22.8^{ABCDE}
T_3	10.9	10.7	67.3^{I}	3.13^{D}	7.00	1434^{I}	5016^{K}	6451^{I}	22.2^{FG}
T_4	11.0	10.8	72.1^{GHI}	3.16^{CD}	7.06	1538^{H}	5316^{I}	6853^{G}	22.5^{EFG}
T_5	11.3	11.1	77.1^{EFG}	3.18^{BCD}	7.09	1654^{F}	5716^{G}	7370^{E}	22.5^{EFG}
T_6	11.3	11.1	78.3^{CDEFG}	3.18^{BCD}	7.14	1755^{DE}	6029^{CDE}	7784^{C}	22.6^{DEFG}
T_7	11.1	11.0	70.7^{HI}	3.13^{D}	7.01	1495^{H}	5162^{J}	6657^{H}	22.5^{EFG}
T_8	11.1	10.9	75.1^{FGH}	3.16^{CD}	7.07	1589^{G}	5464^{H}	7052^{F}	22.5^{DEFG}
T_9	11.3	11.1	79.2^{CDEF}	3.18^{BCD}	7.15	1761^{D}	5985^{E}	7745^{C}	22.7^{CDEF}
T_{10}	11.4	11.2	82.7^{BCDE}	3.20^{BCD}	7.16	1778^{D}	6010^{DE}	7787^{C}	22.8^{BCDE}
T_{11}	11.3	11.1	82.9^{BCDE}	3.22^{ABC}	7.18	1828^{C}	6122^{BCD}	7950^{B}	23.0^{ABCDE}
T_{12}	11.5	11.3	83.3^{BCD}	3.22^{ABC}	7.21	1839^{C}	6135^{BC}	7974^{B}	23.1^{ABCD}
T_{13}	11.3	11.2	84.4^{BC}	3.23^{ABC}	7.21	1861^{BC}	6145^{ABC}	8006^{B}	23.2^{ABC}
T_{14}	11.5	11.3	86.0^{B}	3.23^{ABC}	7.22	1873^{ABC}	6170^{AB}	8043^{AB}	23.3^{ABC}
T_{15}	11.3	11.1	76.2^{FGH}	3.18^{BCD}	7.07	1618^{FG}	5502^{H}	7120^{F}	22.7^{CDEF}
T_{16}	11.6	11.5	92.8^{A}	3.30^{A}	7.22	1914^{A}	6259^{A}	8172^{A}	23.4^{A}
T_{17}	10.8	10.7	29.3^{J}	3.12^{D}	7.00	621^{J}	2179^{L}	2801^{J}	22.1^{G}
T_{18}	10.6	10.4	86.8^{AB}	3.26^{AB}	7.22	1890^{AB}	6193^{AB}	8083^{AB}	23.4^{AB}

Value with atleast one letter common are not significantly different.

in weedy check treatment was recorded due to abundance of weeds that competes efficiently with crop plants of pigeonpea for moisture, nutrient, space and sunlight. The findings are in collaboration with results reported by Talnikar *et al.* (2008) and Channappagoudar and Biradar (2007). Among all herbicidal treatments, the highest yield and yield attributes were recorded in PRE application of pendimethalin + imazethapyr @ 1000 + 75 g/ha and similar results was also reported by Kumar *et al.* (2015).

Keeping the field weed free *via* hoeing is laborious, time consuming and costlier weed management practice. In pigeonpea which is a rainy season crop in Haryana is not possible to employee hoeing in rainy condition. Therefore, pre emergence application of pendimethalin + imazethapyr @ 1000 + 75 g/ha proved to be an effective and a profitable alternative to the existing recommendation (two hoeings at 25 and 45 DAS) of weed control in pigeonpea in Haryana locality.

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