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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(7): 1074-1077

www.thepharmajournal.com
Received: 14-05-2021
Accepted: 26-06-2021

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Effect of integrated weed management with new herbicide mixtures on growth, yield and weed dynamics in chick pea

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Abstract
A field experiment was conducted at Agricultural Research Institute Main Farm, Professor Jayashankar Telangana State Agriculture University, Rajendranagar, Hyderabad, Telangana during *rabi* 2020-21 to evaluate the effect of integrated weed management with new herbicide mixtures in chick pea (*Cicer arietinum*). The experiment consisted of 12 treatments laid out in completely randomised design and replicated thrice. Results revealed that application of Pendimethalin 30% + imazethapyr 2% EC-ready mix @ 1.0 kg ha^{-1} as PE *fb* mechanical weeding at 30 DAS, Pendimethalin 30% EC @ 1 kg ha^{-1} as PE *fb* mechanical weeding at 20 & 40 DAS, Oxyfluorfen 23.5% EC @ 140 g ha^{-1} as PE *fb* mechanical weeding at 20 & 40 DAS recorded lowest weed density, dry weight, higher weed control efficiency, herbicide efficiency index, lower weed index, higher seed and haulm yield.

Keywords: Integrated weed management, new herbicide mixtures, weed indices, chick pea, Yield

Introduction
Pulses being versatile in nature, adapt to a wide range of edaphic and climatic conditions henceforth, constitute a crucial segment of climate change mitigation and adaption strategy (Singh *et al*. 2020) [12]. Among the *rabi* pulses pulses, chick pea is an important crop, and accounts for about 44.5% of total pulse production from 35.1% of total pulse area. It has good qualities like low glycemic index, gluten-free and acts as a functional food (Rao, 2002) [11] and has beneficial effects on some of the important human diseases such as cardiovascular disease (CVD), Type 2 diabetes, digestive diseases and some type of cancers. Among the constraints faced in chick pea cultivation, the most troublesome one is competition from weeds as it is not a weed competitive crop, especially at early stages due to slow growth (Barker, 2017) [1]. The yield losses in chick pea due to weeds range from 30-54% (Mukherjee, 2007) [7].
Weeds in chick pea are commonly controlled by conventional methods (cultural manipulation either by hand weeding or hoeing) which is very effective but, laborious and expensive. Further, chemical weed control in chick pea is confined to pre-emergence herbicides like pendimethalin, Alachlor and Oxyflorfen etc.; which control weeds only to very shorter period with a offering high crop weed competition till critical crop growth period. Hence, there is an urgent need to identify a economically and environmentally safe and sustainable weed management strategy involving broad-spectrum new generation post emergence herbicide molecules for effective weed control till the critical period of weed competition apart from improving the productivity and profitability of chick pea.

Materials and Methods
The experiment was conducted at Main Farm, Agricultural Research Institute, Professor Jayashankar Telangana State Agriculture University), Rajendranagar, Hyderabad. The experiment site is geographically located at 17° 3’ N latitude, 78° 39’ E longitude and an altitude of 494 m above mean sea level and 1 km away from Indian Institute of Rice Research and falls under semi-arid tropics according to Troll’s climatic classification. The weekly mean maximum temperature during the crop growth period ranged from 26.36 ^{0}C to 31.64 ^{0}C with an average of 29.23 ^{0}C. The weekly mean minimum temperature during the crop period ranged from 11.07 ^{0}C to 21.64 ^{0}C with an average of 15.55 ^{0}C. The weekly mean relative humidity in the morning (RH-I) during the crop season ranged from 83.86 to 98.14 percent with an average of 92.75 percent while, the weekly mean relative humidity in the afternoon (RH-II) varied from 36.43 to 82.43 percent with an average of 49.21 percent. The soil of experimental site

was clay in texture, slightly alkaline in reaction (pH 8.2), high in organic carbon (0.98%), medium in available nitrogen (290.5 kg ha^{-1}) and available Phosphorus (40.5 kg ha^{-1}) and high in available Potassium (400.8 kg ha^{-1}). The cultivar JG-^{1}1 was sown on 6th November, 2020 after rhizobium inoculation by adopting 30 cm inter-row and 10 cm intra-row spacing. Recommended dose of fertilizers *viz.*; 20 kg N ha^{-1} was applied in 2 equal splits, 50% as basal through Diammonium phosphate (DAP) along with uniform dose of phosphorus (50 kg ha^{-1}) and potassium (20 kg ha^{-1}) through DAP and Muriate of potash respectively. Remaining 50% N was applied at 30 days after sowing through urea. Biometric observations on the morpho-physiological parameters were taken on tagged five representative plants selected at random from each treatment of net plot and the mean values were presented. Pre-emergence herbicides were applied after sowing of crop and post- emergence herbicides (Table 1) were sprayed at 25 DAS with knapsack sprayer using 500 litres of water per hectare.

Table 1: Treatment details

T. No.	Treatments	Dose ha^{-1}	Time of application
T1	Pendimethalin 30% EC fb mechanical weeding at 20 & 40 DAS	1000 g ha^{-1}	PE
T2	Pendimethalin 30% + imazethapyr 2% EC(RM) fb mechanical weeding at 30 DAS	1000 g ha^{-1}	PE
T3	Oxyfluorfen 23.5% EC fb mechanical weeding at 20 & 40 DAS	140 g ha^{-1}	PE
T4	Imazethapyr 10% SL fb mechanical weeding at 40 DAS	60 g ha^{-1}	PoE (2-4 leaf stage of weed)
T5	Topramezone 33.6% SC fb mechanical weeding at 40 DAS	25.2 g ha^{-1}	PoE (2-4 leaf stage of weed)
T6	Imazethapyr 35% + imazamox 35% WG (RM) fb mechanical weeding at 40 DAS	70 g ha^{-1}	PoE (2-4 leaf stage of weed)
T7	Propaquizafop 10% EC + imazethapyr 10% SL (TM) fb mechanical weeding at 40 DAS	62.5 + 60 g ha^{-1}	PoE (2-4 leaf stage of weed)
T8	Quizalofop ethyl 5% EC + imazethapyr 10% SL (TM) fb mechanical weeding at 40 DAS	50 + 60 g ha^{-1}	PoE (2-4 leaf stage of weed)
T9	Aciefluorfen 16.5% + clodinofop propargyl 8% EC (RM) fb mechanical weeding at 40 DAS	245 g ha^{-1}	PoE (2-4 leaf stage of weed)
T10	Fluazifop-p-butyl 11.1 + fomesafen 11.1% SL (RM) fb mechanical weeding at 40 DAS	250 g ha^{-1}	PoE (2-4 leaf stage of weed)
T11	Mechanical weeding at 20 and 40 DAS	-	-
T12	Weedy Check	-	-

****Note:** PE-Pre-emergence; PoE-post emergence; TM-Tank mixed; RM-Ready mix

Weed density was recorded by using 0.25 m^2 quadrat in all the treatments and then converted into weeds m^{-2}. Weeds were dried in oven till constant weight was attained. Data on weed density and dry weight transformed to g m^{-2} by using square root transformation ($\sqrt{x} + 1$) to normalize their distribution (Gomez and Gomez, 1984) [3]. The weed control efficiency and weed index were calculated by the formulae:

$$\text{Weed control efficiency (\%)} = \frac{WDM_c - WDM_t}{WDM_c} \times 100$$

(Umrani and Boi, 1982) [13]

Where

WDM_c = Weed dry weight (g m^{-2}) in control plot

WDM_t = Weed dry weight (g m^{-2}) in treated plot

$$\text{Herbicide efficiency index (\%)} = HEI = \frac{Y_T - Y_C}{Y_T} \times \frac{WDM_C}{WDM_T}$$

(Krishnamurthy *et al*, 1975) [5]

Where

Y_T = Crop yield from treated plot

WDM_C = Weed dry matter in control

Y_C = Crop yield from control plot

WDM_C = Weed dry matter in treatment

$$\text{Weed index (\%)} = \frac{X - Y}{X} \times 100$$

(Gill and Vijay Kumar, 1969) [2]

Where

X = Yield from minimum weed competition plot

Y = Yield from the treatment plot

Results and Discussion

Effect on weeds

Broad leaved weeds were dominant in the experimental plots. All the weed management practices significantly affected the weed density and weed dry weight in comparison to weedy check (Table 2). At 40 DAS, weedy check recorded highest weed density and dry weight (15.8 m^{-2} and 6.24 g m^{-2}). Among the weed control practices, Pendimethalin 30% + imazethapyr 2% EC (RM) @ 1 kg ha^{-1} as PE fb mechanical weeding at 30 DAS maintained superiority and registered lowest weed density and weed dry weight (4.7 m^{-2} and 2.35 g m^{-2}) which was on par with Pendimethalin 30% EC @ 1 kg ha^{-1} as PE fb mechanical weeding at 20 & 40 DAS (4.8 m^{-2} and 2.37 g m^{-2}), Oxyfluorfen 23.5% EC @ 140 g ha^{-1} as PE fb mechanical weeding at 20 and 40 DAS (5.2 m^{-2} and 2.67 g). The treatments Topramezone 33.6% SC @ 25.2 g ha^{-1} as (PoE) fb mechanical weeding at 40 DAS and Mechanical weeding at 20 and 40 DAS were on par with above treatments in terms of weed density (5.5 m^{-2} and 5.5 m^{-2}) at 40 DAS but, the weed dry weight under these two treatments was significantly higher (2.91 m^{-2} and 2.71 g m^{-2}). Similar findings on lower weed density due to application of pre-emergence and post emergence herbicide application were earlier reported by Parihar *et al.* (2019) [8]. Broad-spectrum nature of pendimethalin which killed weeds by inhibiting cell division and elongation. Imazethapyr which acted as inhibitor of three branched-chain amino-acids and thus, resulted in lesser weed count and ultimately produced lower weed dry weight. The results were in line with Indu *et al.* (2021) [4].

Contrary to 40 DAS, at 60 DAS, the weed density and weed dry weight in Topramezone were lowest than rest of the treatments (5.5 m^{-2} and 2.93 g m^{-2}) but, it was on par with only Pendimethalin 30% + imazethapyr 2% EC (RM) @ 1 kg ha^{-1} as PE fb mechanical weeding at 30 DAS (6.7 m^{-2} and 3.28 g m^{-2}). Lower weed density and dry weight at 60 DAS with Topramezone was due to the residual effect of Topramezone which has half-life of >120 days (Lavanya *et al*. 2021) [6]. These were followed by Pendimethalin 30% EC @ 1 kg ha^{-1} as PE fb mechanical weeding at 20 & 40 DAS (7.6 and 3.43 g m^{-2}), Oxyfluorfen 23.5% EC @ 140 g ha^{-1} as PE fb mechanical weeding at 20 and 40 DAS (7.9 m^{-2} and 3.45 g m^{-2}), mechanical weeding at 20 and 40 DAS (8.1 and 3.45g) Propaquizafop 10% EC + imazethapyr 10% SL (TM) @ (62.5 + 60) (8.9 m^{-2} and 5.06 g m^{-2}) Quizalofop ethyl 5% EC + imazethapyr 10% SL (TM) @ (50 + 60) g ha^{-1} as (PoE) fb mechanical weeding at 40 DAS (10.5 and 5.19 g), Fluazifop-p-butyl 11.1 + fomesafen 11.1% SL (RM) @ 250 g ha^{-1} as (PoE) fb mechanical weeding at 40 DAS (11.9 and 5.35 g m^{-2}) and Mechanical weeding at 20 and 40 DAS (8.1 m^{-2} and 7.47 g m^{-2}). Weedy check recorded highest weed density and dry weight (16.0m^{-2} and 7.47 g).

Weed indices

Weed control efficiency and herbicide efficiency index

Weed control efficiency and herbicide efficiency index at 40 DAS was highest with Pendimethalin 30% + imazethapyr 2% EC (RM) @ 1 kg ha^{-1} as PE fb mechanical weeding at 30 DAS registered highest weed control efficiency (88.09 and 3.89%) followed by Pendimethalin 30% EC @ 1 kg ha^{-1} as PE fb mechanical weeding at 20 & 40 DAS (85.17 and 2.90%), Oxyfluorfen 23.5% EC @ 140 g ha^{-1} as PE fb mechanical weeding at 20 & 40 DAS (83.76 and 2.60%). At 60 DAS Topramezone 33.6% SC @ 25.2 g ha^{-1} as (PoE) fb mechanical weeding at 40 DAS recorded highest weed control efficiency (86.12 and 2.31) followed by Pendimethalin 30% + imazethapyr 2% EC (RM) @ 1 kg ha^{-1} as PE fb mechanical weeding at 30 DAS (82.14 and 2.60%) and Pendimethalin 30% EC @ 1 kg ha^{-1} as PE fb mechanical weeding at 20 & 40 DAS (80.40 and 2.19%). Higher weed control efficiency and herbicide efficiency index were due to lowest weed dry matter and higher seed yield over rest of the treatments. Similar findings were reported by Poonia and Pithia, 2013 [13] and Singh *et al*. 2020 [12].

Weed index

Among the treatments lowest weed index was registered with Pendimethalin 30% EC @ 1 kg ha^{-1} as PE fb mechanical weeding at 20 & 40 DAS (6.0%) followed by Oxyfluorfen 23.5% EC @ 140 g ha^{-1} as PE fb mechanical weeding at 20 & 40 DAS (6.5%) and Mechanical weeding at 20 and 40 DAS (16.4%). Lower weed index values were due to better weed control coupled with higher seed yield (Patel *et al*. 2016) [9].

Effect on crop

Growth parameters

Among the weed control treatments, Pendimethalin 30% + imazethapyr 2% EC (RM) @ 1.0 kg a.i. ha^{-1} as PE fb mechanical weeding at 30 DAS registered maximum number of branches, leaf area and dry matter production (23.06, 937.13 cm^2 and 3512 kg ha^{-1}) and it was equally superior to Pendimethalin 30% EC @ 1 kg ha^{-1} as PE fb mechanical weeding at 20 and 40 DAS (21.33, 558.10 cm^2 and 3300 kg ha^{-1}) followed by was Oxyfluorfen 23.5% EC @ 140 g ha^{-1} as PE fb mechanical weeding at 20 and 40 DAS (18.46, 512.48 cm2and 2860 kg ha^{-1}). Weedy check registered lowest number of branches (10.00, 274.00 cm^2 and 1707 kg ha^{-1}). Improved number of branches were due to higher weed control efficiency, herbicide efficiency index that offered lesser crop - weed competition for nutrients, moisture, space and sunlight (Poonia and Pithia, 2013) [13].

Yield attributes and yield

The treatment Pendimethalin 30% + imazethapyr 2% EC (RM) @ 1 kg ha^{-1} as PE fb mechanical weeding at 30 DAS produced higher number of pods plant $^{-1}$, seed yield plant^{-1}, seed and haulm yield (48.40, 9.39 g plant^{-1}, 2076 and 2618 kg ha^{-1}) but, equally superior to Pendimethalin 30% EC @ 1 kg ha^{-1} as PE fb mechanical weeding at 20 & 40 DAS (43.27, 8.25 g plant^{-1}, 1951 and 2179 kg ha^{-1}) and Oxyfluorfen 23.5% EC @ 140 g ha^{-1} as PE fb mechanical weeding at 20 & 40 DAS (41.53, 8.10 g plant^{-1}, 1941 and 2079 kg ha^{-1}). The lowest number of pods plant $^{-1}$, seed yield plant^{-1}, seed and haulm yield (25.20, 4.96 g plant^{-1}, 1112 and 1364 kg ha^{-1}) were observed in weedy check (Table 3). Higher weed control efficiency improved growth parameters, pods plant^{-1} and lower weed index values in these treatments reflected in higher seed and haulm yield. However, lower yield recorded with Topramezone 33.6% SC @ 25.2 g ha^{-1} as (PoE) fb mechanical weeding at 40 DAS was due to slight phytotoxicity and persistence in the soil till harvest. These results are in line with those of Indu *et al*. 2021 [4].

Conclusion: It could be concluded that in chick pea crop, integrated weed management with Pendimethalin 30% + imazethapyr 2% EC ready mix @ 1 kg ha^{-1} as PE fb mechanical weeding at 30 DAS, Pendimethalin 30% EC @ 1 kg ha^{-1} as PE and mechanical weeding at 20 & 40 DAS and Oxyfluorfen 23.5% EC @ 140 g ha^{-1} as PE fb mechanical weeding at 20 & 40 DAS offered effective weed control and improved the crop growth, yield attributes and yield.

Table 2: Effect of weed control treatments on weed density, dry weight and weed indices

Treatments	Total weed density 40 DAS (No. m^{-2})	Total weed density 60 DAS (No. m^{-2})	Weed dry weight 40 DAS (g m^{-2})	Weed dry weight 60 DAS (g m^{-2})	WCE 40 DAS (%)	WCE 60 DAS (%)	HEI 40 DAS (%)	HEI 60 DAS (%)	Weed index (%)
T1	4.8 (22.0)	7.6 (57.3)	2.57 (5.62)	3.43 (10.73)	85.17	80.40	2.90	2.19	6.0
T2	4.7 (21.3)	6.7 (44.0)	2.35 (4.51)	3.28 (9.78)	88.09	82.14	3.89	2.60	-
T3	5.2 (25.6)	7.9 (60.6)	2.67 (6.15)	3.45 (10.91)	83.76	80.08	2.63	2.14	6.5
T4	9.0 (79.3)	13.1 (171.3)	3.66 (12.43)	5.89 (33.67)	67.19	38.53	0.37	0.20	39.1
T5	5.5 (29.3)	5.5 (29.3)	2.91 (7.45)	2.93 (7.60)	80.33	86.12	0.63	2.31	21.0
T6	9.2 (84.0)	13.2 (173.6)	3.96 (14.7)	6.30 (38.67)	61.19	29.40	0.30	0.17	39.3
T7	7.2 (50.7)	8.9 (77.3)	3.05 (8.29)	5.06 (24.63)	78.11	55.02	1.18	0.57	27.7
T8	7.4 (54.0)	10.5 (109.3)	3.27 (9.69)	5.19 (25.90)	74.41	52.71	0.99	0.54	28.2
T9	8.7 (74.0)	12.6 (158.6)	3.61 (12.05)	5.71 (31.60)	68.20	42.30	0.53	0.29	35.6
T10	8.5 (71.2)	11.9 (139.9)	3.42 (10.70)	5.35 (27.60)	71.75	49.60	0.67	0.37	33.9
T11	5.5 (29.9)	8.1 (64.0)	2.79 (6.78)	3.64 (12.27)	82.10	77.60	-	-	16.4
T12	15.8 (250.0)	16.0 (255.6)	6.24 (37.88)	7.47 (54.77)	0.00	0.00	-	-	46.4

S.Em±	0.78	0.78	0.16	0.20	-	-	-	2.19	-
CD (P = 0.05)	2.30	2.30	0.47	0.58	-	-	-	2.60	-

Note: Figures in parenthesis are transformed values, square root transformation ($\sqrt{x} + 1$) was used for statistical analysis

Table 3: Effect of weed control treatments on growth, yield attributes and yield of chick pea

Treatments	Branches plant^{-1}	Leaf area (cm^2 plant^{-1})	Dry matter production (kg ha^{-1})	Pods plant	Seed yield plant^{-1} (g)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T1	21.33	558.10	3300	43.27	8.25	1951	2179
T2	23.06	937.13	3512	48.40	9.39	2076	2618
T3	18.46	512.48	2860	41.53	8.10	1941	2079
T4	12.20	301.07	2200	29.00	5.58	1264	1420
T5	14.26	375.22	2537	37.20	6.30	1639	1898
T6	12.00	283.91	2100	28.00	5.49	1261	1410
T7	13.40	330.90	2430	35.93	6.20	1500	1712
T8	13.33	321.00	2370	33.53	6.10	1490	1708
T9	12.33	305.00	2237	28.73	5.92	1337	1428
T10	12.66	308.09	2357	29.27	5.99	1372	1572
T11	17.20	504.90	2801	39.07	6.67	1735	1975
T12	10.00	274.00	1707	25.20	4.96	1112	1364
S.Em±	0.79	14.82	73.00	1.15	0.26	88	56
CD (P = 0.05)	2.31	43.45	214	3.37	0.76	258	165

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