



Elucidating the impact of new-generation herbicides on productivity and phytotoxicity on chickpea (*Cicer arietinum*) and their residual effects

G D SANKETH¹, K BHANU REKHA², KAPILA SHEKHAWAT^{1*}, Y CHAITHANYA²,
T RAM PRAKASH² and K S SUDHAKAR²

Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana 500 030, India

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Chickpea (*Cicer arietinum* L.) is the most important winter (*rabi*) season pulse crop in India which accounts for ~44.5% of total pulse production from 35.1% of total area under pulses. The average chickpea production in India remains ~11.9 million tonnes from 8.8 million hectares area with the national productivity of 1.11 t/ha (Anonymous 2022). Among the several biotic constraints limiting the chickpea yield, weeds occupy the primary position. Weeds compete with crop plants for resources, particularly in the initial stages which reduce growth and productivity. If weed growth remains unchecked at critical periods of crop weed competition, the yield losses in chickpea may account up to 50% (Akashdeep *et al.* 2020). Traditional weed management methods in chickpea involve manual weeding or hoeing, which are effective but are labour-intensive and expensive. Chemical weed management through the use of herbicide mixtures effectively offers wide spectrum weeds control. However, it offers limited choice in chickpea due to its sensitivity to most of the herbicides. New-generation low-dose and high-efficacy herbicides have been found more effective in weed control with minimum effect on crops and environment. They manage weed pressures, enhance crop yields and promote sustainable agricultural practices. Hence an attempt was made to study the efficacy of ready and tank mix herbicides in managing weeds in chickpea.

The present study was carried out at Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana during 2021. The experiment consisted of 12 treatments and 3 replications, viz. T₁, Pendimethalin @1 kg/ha pre-emergence (PE) fb mechanical weeding (MW) at 20 and 40 DAS (Days after sowing); T₂, Pendimethalin + imazethapyr ready mix (RM)

1 kg/ha (PE) fb MW at 30 DAS; T₃, Oxyfluorfen @140 g/ha (PE) fb MW at 20 and 40 DAS; T₄, Imazethapyr @60 g/ha post-emergence (PoE) fb MW at 40 DAS; T₅, Topramezone @25.2 g/ha (PoE) fb MW at 40 DAS; T₆, Imazethapyr 35% + imazamox (RM) @70 g/ha (PoE) fb MW at 40 DAS; T₇, Propaquizafop + imazethapyr tank mix (TM) @62.5 + 60 g/ha (PoE) fb MW at 40 DAS; T₈, Quizalofop ethyl + imazethapyr (TM) @50 + 60 g/ha (PoE) fb MW at 40 DAS; T₉, Acifluorfen + clodinafop propargyl (RM) @245 g/ha (PoE) fb MW at 40 DAS; T₁₀, Fluazifop-p-butyl + fomesafen (RM) @250 g/ha (PoE) fb MW at 40 DAS; T₁₁, MW at 20 and 40 DAS; T₁₂, Weedy check (WC).

The soil of experimental site was clayey in texture, slightly alkaline in reaction (pH 8.2), high in organic carbon (0.98%), medium in available N (290.5 kg/ha), P (17.4 kg/ha) and high in available K (332.6 kg/ha). Chickpea variety JG-11 was sown on 6th November, 2020 in 30 cm × 10 cm spacing using seed rate of 75 kg/ha and was harvested on 13th February, 2021. The recommended dose of fertilizers as 20 kg N/ha (split application at basal and 30 days after sowing (DAS), 50 kg P/ha (basal) and 20 kg K/ha (basal) were applied in the form of urea, single super phosphate (SSP) and muriate of potash (MOP). The pre-emergence (PE) herbicides application was done one day after sowing of crop and post-emergence (PoE) herbicides application was done at 25–30 DAS. Herbicides were sprayed with a power sprayer using 400 litres of water per hectare. Weed density was recorded by using 0.25 m² quadrat at different intervals in all the treatments and then converted into number/m². The air-dry weed samples were put in a oven till a constant weight was attained and was converted to weed biomass (g/m²). The data on weed density and biomass were subjected to square root transformation to normalize their distribution. The weed control index, herbicide efficiency index and weed index were calculated as:

$$\text{Weed control index (\%)} = \frac{\text{WDMc} - \text{WDMt}}{\text{WDMc}} \times 100 \quad (\text{Umrani and Boi 1982})$$

¹ICAR-Indian Agricultural Research Institute, New Delhi; ²Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana. *Corresponding author email: drathorekapila@gmail.com

$$\text{Herbicide efficiency index (HEI)} = \frac{Y_t - Y_c}{Y_t} \times \frac{\text{WDMc}}{\text{WDM}} \quad (\text{Krishnamurthy et al. 1975})$$

$$\text{Weed index (\%)} = \frac{X - Y}{X} \times 100 \quad (\text{Gill and Vijay 1969})$$

Where, WDMc, Weed dry weight (g/m²) in control plot; WDMt, Weed dry weight (g /m²) in treated plot; Y_t, Crop yield from treated plot; Y_c, Crop yield from control plot; X, Yield from minimum weed competition plot and; Y, Yield from the treatment plot. After the harvest of chickpea, about 2 kg soil was collected from each treatment plot from the depth of 0–10 cm. The soil was quartered and 250 g of soil from each of the treatment plots was weighed and filled in the pots. A set of three experiments consisting of a total of 108 pots (12 × 3 × 3) were maintained in order to evaluate the residual effect of different herbicides on the succeeding crops. Three test crops, viz. tomato, cucumber and finger millet were selected to assess the residual effect of herbicides and herbicidal mixtures applied to chickpea crops. Seed of each test crop was sown in 36 pots (12 treatments × 3 replications) with a total of 108 pots for 3 crops, arranged in a complete randomized block design (CRBD) design.

Vigour index 1 = Germination (%) × seedling length (cm)

Vigour index 2 = Germination (%) × seedling dry weight (g), (Abdul-Baki and Anderson 1973)

Weed control index (WCI), herbicide efficiency index (HEI) and weed index (WI): The major weed flora observed in the experiment were *Physalis minima*, *Parthenium hysterophorus* and *Panicum* sp. The WCI and HEI at 40 DAS were recorded highest with pendimethalin + imazethapyr (RM) @1 kg/ha as PE fb MW at 30 DAS (88.1% and 3.9)

followed by pendimethalin @1 kg/ha as PE fb MW at 20 and 40 DAS (85.2 % and 2.9), oxyfluorfen @140 g/ha as PE fb MW at 20 and 40 DAS (83.8 % and 2.6) (Table 1). Higher WCI and HEI in T₂ were due to lowest weed dry matter at critical crop weed competition period (CCWCP) and higher seed yield over rest of the treatments. Singh *et al.* (2020) also suggest that due to broad spectrum weed control by pendimethalin and imazethapyr during CCWCP has been found more effective (persistence of 30–40 days after spraying). At 60 DAS, topramezone @25.2 g/ha as (PoE) fb MW at 40 DAS recorded highest WCI and HEI (86.1 and 2.3%) followed by other treatments, due to long term residual effect of topramezone herbicide compared to that of other herbicide mixtures. Among the treatments, lowest weed index was registered with pendimethalin @1 kg/ha as PE fb MW at 20 and 40 DAS (6.0%) followed by oxyfluorfen @140 g/ha as PE fb MW at 20 and 40 DAS (6.5%) and MW at 20 and 40 DAS (16.4%). Lower weed index values were due to better weed control that resulted in lower weed dry weight coupled with higher seed yield.

Agronomic productivity (t/ha): The results on seed yield revealed that the plots that were subjected to spraying with pendimethalin + imazethapyr (RM) @1 kg/ha as PE fb MW at 30 DAS recorded significantly higher seed yield of 2.08 t/ha. However, this yield was comparable to the application of pendimethalin @1 kg/ha as PE fb MW at 20 and 40 DAS, oxyfluorfen @140 g/ha as PE fb MW at 20 and 40 DAS, which recorded seed yields of 1.95 and 1.94 t/ha, respectively (Table 1). The lowest seed yield of 1.11 t/ha was obtained from the weedy check. The improved seed yield in T₂ may be due to higher WCI and HEI during CCWCP (which restricted weed growth due to inhibition of photosystem-I and branched chain amino acids which are responsible for weed growth). This facilitated the crop to produce more assimilatory surface, dry matter, which in turn

Table 1 Effect of weed control treatments on weed control index (WCI), herbicide efficiency index (HEI), weed index (WI) and seed yield

Treatment	Weed control index (%)		Herbicide efficiency index		Weed index (%)	Seed yield (t/ha)
	40 DAS	60 DAS	40 DAS	60 DAS		
T ₁	85.2	80.4	2.9	2.2	6.0	1.95
T ₂	88.1	82.1	3.9	2.6	0.0	2.08
T ₃	83.8	80.1	2.6	2.1	6.5	1.94
T ₄	67.2	38.5	0.4	0.2	39.1	1.26
T ₅	80.3	86.1	0.6	2.3	21.0	1.64
T ₆	61.2	29.4	0.3	0.2	39.3	1.26
T ₇	78.1	55.0	1.2	0.6	27.7	1.50
T ₈	74.4	52.7	1.0	0.5	28.2	1.49
T ₉	68.2	42.3	0.5	0.3	35.6	1.34
T ₁₀	71.8	49.6	0.7	0.4	33.9	1.37
T ₁₁	82.1	77.6	-	-	16.4	1.73
T ₁₂	0.0	0.0	-	-	46.4	1.11
LSD (P=0.05)						0.258

Refer to the methodology for treatment details.



Fig 1 Residual effect of Topramezone @25.2 g/ha on succeeding bioassay (pot culture).



Fig 2 Residual effect of odyssey @70 g/ha on succeeding bioassay (pot culture).

increased nutrient uptake and finally, produced higher seed yield. Pendimethalin + imazethapyr ready mix (RM) @1 kg/ha (PE) fb MW at 30 DAS recorded higher B:C ratio (3.27) with single MW which also decreased drudgery compared to that of other PE treatments. The results reported by Indu *et al.* (2021) were in line with these findings.

Phytotoxic effect on chickpea crop: The phytotoxicity symptoms on chickpea were visualized after imposition

of PoE herbicides from 30–55 days of crop growth. In the treatments, viz. T₄ [acetolactate synthase (ALS) and acetohydroxyacid synthase (AHAS) inhibitor], T₅ [4-Hydroxyphenylpyruvate dioxygenase (HPPD) inhibitor], T₆ (ALS and AHAS inhibitor), T₇ [Acetyl-CoA carboxylase (ACC) inhibitor along with ALS and AHAS inhibitor] and T₈ (ACC inhibitor along with ALS and AHAS inhibitor) yellowing of apical portion of the plant was observed after 7

Table 2 Residual effect of different herbicide treatments on vigour index of succeeding crops

Treatment	Vigour index- I			Vigour index - II		
	Tomato	Cucumber	Finger Millet	Tomato	Cucumber	Finger Millet
T ₁	1170	1458	1493	22.2	40.6	32.1
T ₂	945	1811	1592	17.2	42.7	34.7
T ₃	747	1213	1367	5.9	40.5	31.4
T ₄	538	843	756	3.3	34.4	25.8
T ₅	0	0	0	0.0	0.0	0.0
T ₆	280	420	613	2.1	16.4	17.1
T ₇	563	750	1305	4.2	34.7	33.2
T ₈	537	1027	1224	4.2	40.7	29.4
T ₉	653	967	978	10.6	43.9	31.1
T ₁₀	607	958	1194	7.6	34.7	32.3
T ₁₁	1250	1550	1600	18.2	44.2	36.6
T ₁₂	1300	1750	1632	20.1	49.3	36.6

Refer to the methodology for treatment details.

days of treatment imposition and it gradually decreased after 21 days of application. The yellowing in these treatments was probably recorded due to loss of chlorophyll content which resulted in lower photosynthesis. The stunting of crops was also due to lack of the synthesis of essential amino acids, viz. leucine, isoleucine and valine which is required for normal crop growth and development. The phytotoxic effect also delayed the onset of flowering in the crop. Similar findings suggesting yellowing in chickpea with the application of imazethapyr @63 g/ha have been documented by Ratnam *et al.* 2011.

In the treatments, viz. T₄, T₅, T₆, T₇, T₈, T₉ [Protoporphyrinogen oxidase (PPO) inhibitor and ACC inhibitor] and T₁₀ (PPO inhibitor and ACC inhibitor), stunting of crops was observed after 7 days of treatment imposition. The stunting associated with these treatments was due to slow photosynthetic rate, crop growth and also due to yellowing. The necrosis of the crop was seen with treatments, viz. T₉ and T₁₀ after 7 days of spraying. The necrosis of the crop's apical portion decreased the leaf area and chlorophyll content and overall photosynthetic process. The application of imazethapyr @70 g/ha, imazethapyr @100 g/ha and imazethapyr + imazamox @70 g/ha resulted in leaf chlorosis, followed by necrosis in greengram (Yadav *et al.* 2018). These phytotoxic effects on crop plants at their active vegetative growth stage led to poor seed and haulm yield.

Herbicide residual effects: The residual studies conducted in the succeeding tomato, cucumber and finger millet crops in the pots indicated that topramezone @25.2 g/ha *fb* MW at 40 DAS (PoE) resulted in poor germination (30.0, 33.3 and 40.0%, respectively) in all the 3 test crops. The effect was also evident in imazethapyr + imazamox (RM) @70 g/ha as (PoE) *fb* MW at 40 DAS where the germination was 46.6, 46.6 and 51.1%, respectively. It also led to lower vigour index-I and vigour index-II (Table 2) (Fig 1 and 2) due to the residual effects of herbicides. Further observation from the present residual studies indicated complete death of all the three test crops seedlings under T₅ at 30 DAS. This could be ascribed to the prolonged residual effect of topramezone in maize field with a half-life of >120 days (Lavanya *et al.* 2021).

SUMMARY

The study suggests that in chickpea higher WCI, HEI and lower WI were noticed with the application of

pendimethalin + imazethapyr 1.0 kg/ha as PE *fb* MW at 30 DAS. Although the application of topramezone @25.2 g/ha as PoE *fb* MW at 40 DAS (T₅) resulted in higher WCI and lesser weed dry weight at both 60 and 90 DAS, the residual effect of this treatment was evident on the succeeding crops. Thus, standardization of the dose of topramezone for chickpea without any phytotoxic effect on the succeeding crops would pave the way for effective weed management in a cropping system mode.

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