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Management of weeds in chickpea + linseed (2:1) intercropping through pre and post emergence herbicides

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Abstract
A field experiment was conducted in Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *rabi* 2019 to study the management of weeds in chickpea + linseed (2:1) intercropping through pre and post emergence herbicides. The experiment was replicated thrice in split plot design with sole chickpea, sole linseed and chickpea + linseed (2:1) intercropping as main plots and pendimethalin 30 EC at 1 kg ha^{-1} (PE), imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS, pendimethalin 30 EC at 1 kg ha^{-1} (PE) *fb* imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS, weed free and weedy check as sub plot treatments. Chickpea + linseed (2:1) intercropping (4.80 m^{-2} and 60.18% respectively) showed on par observation with sole chickpea (4.76 m^{-2} and 62.40% respectively) for weed density and weed control efficiency at 60 DAS. However, intercropping (1126 kg ha^{-1}, ₹ 30307 ha^{-1} and 2.05 respectively) recorded significantly higher chickpea equivalent yield, net return and B C ratio than sole chickpea (1072 kg ha^{-1}, ₹ 22885 ha^{-1} and 1.79 respectively) and sole linseed (1043 kg ha^{-1}, ₹ 24201 ha^{-1} and 1.93 respectively). Among weed management practices, sequential application of pendimethalin 30 EC at 1 kg ha^{-1} (PE) *fb* imazethapyr 10 SL at 50 g ha^{-1} at 20 DAS (EPoE) (4.46 m^{-2}, 86.51%, 1254 kg ha^{-1}, ₹ 35666 ha^{-1} and 2.40 respectively) showed significantly lower weed density, weed control efficiency, chickpea equivalent yield, net return and B C ratio than pendimethalin 30 EC at 1 kg ha^{-1} (PE) (4.67 m^{-2}, 59.23%, 1091 kg ha^{-1}, ₹ 28312 ha^{-1} and 2.12 respectively), imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS (5.11 m^{-2}, 51.38%, 991 kg ha^{-1}, ₹ 24434 ha^{-1} and 1.98 respectively) and weedy check (7.67 m^{-2}, 0.00%, 605 kg ha^{-1}, ₹ 6558 ha^{-1} and 1.28 respectively).

Keywords: Weed management, pendimethalin, imazethapyr, weed control efficiency, net return

Introduction
Chickpea (*Cicer arietinum* L.) is an important pulse crop grown and consumed all over the world, especially in the Asian countries. Chickpea commonly known as Bengal gram and locally as Chana. It is a good source of carbohydrates and protein and the protein quality is considerd to be better than other pulses. It contains major source of protein dietary (18-22%), Carbohydrate (52-70%), fat (4-10%), minerals (calcium, phosphorus, iron) and vitamins for the predominantly vegetarian population of India.

Chickpea is the most important pulse crop of India, which occupied with an area 8.17 m ha^{-1}, production 7.48 m t and productivity 915 kg ha^{-1}. Madhya Pradesh is leading state in the country with 2.63 m ha area, 2.34 m. tones production and an average of 887 Kg ha^{-1} productivity, respectively (Anon., 2018) [1].

Linseed (*Linum usitatissimum* L.) is one of the oldest crop plants cultivated for the purpose of oil and fibre. In India, it is mainly cultivated as an annual rabi oilseeds crop under input starved and moisture stress situation. Depending upon use, linseed is classified into three types. Varieties grown only for seed/oil are known as seed type linseed, whereas, varieties yielding only fibre are known as flax. Varieties grown for getting both seed and fibre are called dual purpose linseed. The plant architect of all three types of linseed is different from each other.

The seed type linseed is shorter with average height of 30 to 50 cm, multi-branched from the base with more number of capsules. The flax plant is taller with average height of 100 to 120 cm with very few branches at the top of the plant. But with advent in research under AICRP on Linseed, such varieties have been developed which can yield good quality fibre as well as seed. Such varieties have average height of 75 to 100 cm and technical height (height between ground to the point where first branch starts) of more than 50 cm with more branches on the

upper part of plant. Recent advances in medical research have found linseed as best herbal source of Omega-3 and Omega-6 fatty acids with immense nutritional/medicinal effect on human body system. Essential Omega-3 fatty acid (ALA) plays an important role in lowering cholesterol, reducing inflammatory disorder like rheumatoids arthritis and providing immunity and cardiovascular benefits. Linseed is one of the richest sources of lignin (800 times more than any other plant seed except sesame seeds 47 times more) which provides protection against certain form of cancer due to estrogenic and anti-estrogenic activity in the body. The use of different grades/form of fibre and seed (raw or oil) in different products.

In our country, linseed occupies 3.26 lakh ha area with a production of 1.73 lakh tonne and contributes about 10.81% (27.77 lakh ha) and 5.31% (27.94 lakh tonne), respectively to the global area and production. In Karnataka, the crop occupies 2000 ha area with a production of 1000 tonne with productivity of 363 kg ha^{-1} (Anon., 2018) [1].

The slow initial growth with lower canopy spread leads to dominance of weeds over the crop. An initial growth period of 25-45 days is very critical and season long weed competition has been found to reduce chickpea and linseed yield to the extent of 30-40% (Mahere *et al.*, 2000) [9] depending on the type and intensity of weed flora. Farmers rely predominately on manual weeding, a traditional method of weed control in oilseeds in general and linseed in particular. Though the conventional methods of weed control are very effective, they are expensive, labour intensive and time consuming during the critical period. This necessitates the development of an alternative cost-effective economically viable weed management practice that can serve as a substitute for manual weeding. In that, herbicides use is making a head way, application of pre-emergence and early post-emergence herbicides was found effective elsewhere for weed control in linseed and other oilseed crops. However, studies in this line are meagre in Karnataka and hence the present study was under taken.

Materials and Methods

A field experiment entitled with "Management of weeds in chickpea + linseed (2:1) intercropping through pre and post emergence herbicides" was conducted in Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *rabi* 2019. The experiment was replicated thrice in split plot design with sole chickpea, sole linseed and chickpea + linseed (2:1) intercropping as main plots and pendimethalin 30 EC at 1 kg ha^{-1} (PE), imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS, pendimethalin 30 EC at 1 kg ha^{-1} (PE) *fb* imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS, weed free and weedy check as sub plot treatments.

Sowing of chickpea (JG-11) and linseed (NL-115) was carried out at 30 cm row spacing on 14th November 2019, with plant to plant spacing of 10 cm for chickpea and 5 cm for linseed. Irrigation was provided with the help of sprinkler for germination of the crops, spraying of pendimethalin at 1 kg ha^{-1} (PE) with the help of sprayer was carried out next day after sowing and spraying of early post emergent herbicide imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 days after sowing for allotted experimental plots.

All the recommended package of practices were implemented except for the weed management practices. Observations on weed density, weed dry weight, weed control efficiency at 30, 60 and 90 days after sowing and weed index after harvest. Observations on growth parameters and yield parameters for chickpea like plant height, number of branches per plant, number of nodules per plant, nodule dry weight, number of pods per plant, number of seeds per pod, test weight, seed yield, stover yield and B C ratio, for linseed like plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule, test weight, seed yield, stover yield and B C ratio was recorded. Calculation on cost of cultivation, gross return, net return and B C ratio as per the treatments. Cropping system parameters *viz*., land equivalent ratio, relative crowding coefficient, crop equivalent yield and area time equivalent ratio estimated for intercropping system.

All above mentioned parameters of were taken and analysed under split plot design. Experimental data obtained was compiled and subjected to statistical analysis by adopting Fischer's method of analysis of variance (Gomez and Gomez, 1984). The critical difference values given in the table at 5 per cent level of significance were used. Weed parameters such as weed density and weed dry weight analyzed by the sqaure root transformation value $\sqrt{x+0.5}$

Results and Discussion

Effect of cropping systems and weed control practices on weeds

The predominant weed spectrum present in the experimental locality consists of grasses, sedges and broad-leaved weeds. Among the grasses, *Cynodon dactylon*, *Brachiaria deflexa and Echinocloa glabrescans*, among sedges, *Cyperus rotundus* and among broad-leaved weeds, *Spilanthus accmella* and *Corchorus olitorius* were the major weeds found in the experimental area. Parallel weed spectrum were noticed by researchers associated with chickpea (Goud *et al*., 2013 and Rathod *et al.*, 2017) [7, 15] and linseed (Siddesh *et al.*, 2016 and Devendra *et al*., 2016) [18, 4].

Total density of weeds (m^{-2}) varied markedly with respect to cropping systems and weed control practices. Among cropping systems, sole chickpea and chickpea + linseed (2:1) intercropping recorded on par observation with each other and significantly lower weed density over sole linseed at 30, 60 and 90 DAS (days after sowing) because of relatively more space was exposed in sole linseed for the growth of weeds. Parallel results noticed by Rahimi *et al.* (2019) [13]. Among weed management practices, absolutely no weeds were noticed in weed free check due to timely hand weeding followed by sequential application of pendimethalin 30 EC at 1 kg ha^{-1} followed by imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS recorded significantly lower weed density than only preemergent application of pendimethalin 30 EC at 1 kg ha^{-1} and only early post emergent application of imazethapyr 10 SL at 50 g ha^{-1} at 20 DAS because sequential application of pre-emergent pendimethalin controls the pre germinating weed seeds followed by early post emergent application of imazethapyr controls the wide range of weeds with systemic action. Weedy check noticed higher weed density due to uncontrolled growth of weed species at 30, 60 and 90 DAS. Parallel findings were noticed by Hargilas (2018) [8] and Pradeepnath (2014) [12].

Dry weight of weeds (g m^{-2}) varied markedly with respect to cropping systems and weed control practices. Among cropping systems, the sole chickpea and chickpea + linseed (2:1) intercropping recorded on par observation with each other and significantly lower weed dry weight with respect to sole linseed at 30, 60 and 90 DAS (days after sowing) because of early and fast growth of chickpea that smothers the lower

vegetation by restricting the solar radiation. Parallel results noticed by Singh *et al.* (2005) [19]. Among weed management practices, weed free check recorded no dry weight of weeds due to timely hand weeding of weeds. Sequential application of pendimethalin 30 EC at 1 kg ha^{-1} as preemergent followed by imazethapyr 10 SL at 50 g ha^{-1} as early post emergent at 20 DAS recorded significantly lower weed dry weight than only preemergent application of pendimethalin 30 EC at 1 kg ha^{-1} and only early post emergent application of imazethapyr 10 SL at 50 g ha^{-1} at 20 DAS because pendimethalin acts as seedling growth inhibitor and imazethapyr acts as amino acid synthesis inhibitor and their sequential application restricts the growth and development of weeds leads lower drymatter accumulation. Weedy check noticed higher weed dry weight due to uncontrolled robust growth of weed species under unlimited growth factors at 30, 60 and 90 DAS. Parallel findings were noticed by Narendra *et al.* (2015) [11] and Chhatrapal (2017) [3].

Weed control efficiency (%) varied markedly with respect to cropping systems and weed control practices. Among cropping systems, sole linseed recorded significantly lower weed control efficiency due to higher weed dry weight and weed density compared to sole chickpea and chickpea + linseed (2:1) intercropping at 30, 60 and 90 DAS. Parallel results were noticed by Dwivedi (1994) [5]. Among weed control methods, weed free check treatment noticed hundred percent of weed control efficiency due to removal of weeds on time, among herbicidal treatments pre-emergent application of pendimethalin 30 EC at 1 kg ha^{-1} followed by early post emergent appliction of imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS sequentially recorded significantly higher weed control efficiency than alone application pendimethalin 30 EC at 1 kg ha^{-1} only and alone application imazethapyr 10 SL at 50 g ha^{-1} only at 20 DAS because combined effect of two herbicides reduced the weed density and weed dry weight that directly relates to the higher control efficiency. Zero percent was noticed in weedy check due to uncontrolled robust growth of weed species under unlimited growth factors at 30, 60 and 90 DAS. Parallel results were noticed by Rupareliya *et al.* (2018) and Chhatrapal (2017) [17, 3].

Weed index (%) varied markedly with respect weed control practices. Cropping systems of sole chickpea, sole linseed and chickpea + linseed (2:1) intercropping recorded non-significant observation for weed index. Parallel results was noticed by Dwivedi (1994) [5]. Among weed control treatments, weed free check noticed zero percent weed index because there was no competition between weeds and crop, among herbicidal treatments sequential application of pendimethalin 30 EC at 1 kg ha^{-1} followed by imazethapyr 10 SL at 50 g ha^{-1} at 20 DAS as pre-emergent and early post emergent respectively recorded significantly lower weed index than pre-emergent application of pendimethalin 30 EC at 1 kg ha^{-1} alone and early post emergent application of imazethapyr 10 SL at 50 g ha^{-1} at 20 DAS alone because less competition is noticed in the treatment due to timely control of weeds by the herbicides. Higher value is obtained in weedy check because massive weed growth in the treatment restricts the normal growth of the crop due to competition for available resources between crop and weeds. Parallel results were noticed by Bhutada and Bhale (2013) [2] and Siddesh *et al.* (2016) [18].

Interaction effect of cropping system and weed management methods noticed non-significant differences for weed density, weed dry weight, weed control efficiency and weed index

Effect of cropping systems and weed control practices on growth, yield parameters and yield of chickpea

Growth and yield parameters varied significantly among the cropping system and weed control practices. Among cropping system, intercropping system recorded significantly higher plant height at 60 DAS and number of pods per plant as compared to sole crop stand because of complimentary effect of intercropping system enhanced the parameters. Other parameters like number of branches per plant, number of nodules per plant, nodule dry weight, number of seeds per pod, test weight recorded non-significant values. Among weed management practices, weed free check recorded higher growth and yield parameters because timely control of weeds enhanced the growth and yield parameters, among herbicidal treatments sequential application of sequential application of pendimethalin 30 EC at 1 kg ha^{-1} followed by imazethapyr 10 SL at 50 g ha^{-1} at 20 DAS as pre-emergent and early post emergent respectively recorded significantly higher growth and yield parameters than alone application of pendimethalin 30 EC at 1 kg ha^{-1} as pre-emergent and alone application of imazethapyr 10 SL at 50 g ha^{-1} at 20 DAS as early post emergent because sequential application hinders the growth and development of weeds which directly relates to the enhanced growth and yield parameters of the crop.

Seed yield (kg ha^{-1}), Stalk yield (kg ha^{-1}) and Harvest index (%) of chickpea varied markedly with respect to cropping systems and weed control practices. Among cropping systems sole chickpea recorded significantly higher value of seed yield, stover yield and harvest index with respect to chickpea + linseed (2:1) intercropping because sole chickpea contains higher plant population compared to their intercropping with linseed. Parallel results were noticed by Singh and Singh (1998) [19]. Among weed management treatments weed free condition recorded higher seed yield and stover yield because of all the essential resources given to treatment was completely utilized by the crop, among herbicidal treatments sequential application of pendimethalin 30 EC at 1 kg ha^{-1} followed by imazethapyr 10 SL at 50 g ha^{-1} at 20 DAS as pre-emergent and early post emergent respectively recorded significantly higher seed yield and stover yield compared as with only pre-emergent application of pendimethalin 30 EC at 1 kg ha^{-1}, only early post emergent application of imazethapyr 10 SL at 50 g ha^{-1}at 20 DAS and weedy condition.

Effect of cropping systems and weed control practices on growth, yield parameters and yield of linseed

Growth and yield parameters varied significantly among the cropping system and weed control practices. Among cropping system, intercropping system recorded significantly higher plant height at 60 DAS and number of capsules per plant as compared to sole crop stand because of complimentary effect of intercropping system enhanced the parameters. Other parameters like number of branches per plant, number of seeds per capsule, test weight recorded non-significant values. Among weed management practices, weed free check recorded higher growth and yield parameters because timely control of weeds enhanced the growth and yield parameters, among herbicidal treatments sequential application of sequential application of pendimethalin 30 EC at 1 kg ha^{-1} followed by imazethapyr 10 SL at 50 g ha^{-1} at 20 DAS as pre-emergent and early post emergent respectively recorded significantly higher growth and yield parameters than alone

application of pendimethalin 30 EC at 1 kg ha^{-1} as pre-emergent and alone application of imazethapyr 10 SL at 50 g ha^{-1} at 20 DAS as early post emergent because sequential application hinders the growth and development of weeds which directly relates to the enhanced growth and yield parameters of the crop.

Seed yield (kg ha^{-1}), Stalk yield (kg ha^{-1}) and Harvest index (%) of linseed varied markedly with respect to cropping systems and weed control practices. Among cropping systems, sole linseed recorded significantly higher value of seed yield, stover yield and harvest index with respect to chickpea + linseed (2:1) intercropping because sole linseed contains higher plant population compared to their intercropping with linseed. Parallel results were noticed by Singh and Singh (1998) [19]. Among weed management treatments weed free condition recorded higher seed yield and stover yield because of all the essential resources given to treatment was completely utilized by the crop, among herbicidal treatments sequential application of pendimethalin 30 EC at 1 kg ha^{-1} followed by imazethapyr 10 SL at 50 g ha^{-1} at 20 DAS as pre-emergent and early post emergent respectively recorded significantly higher seed yield and stover yield compared as with only pre-emergent application of pendimethalin 30 EC at 1 kg ha^{-1}, only early post emergent application of imazethapyr 10 SL at 50 g ha^{-1}at 20 DAS and weedy condition.

Effect of cropping systems and weed control practices on economics

Cost of cultivation (₹ ha^{-1}), gross return (₹ ha^{-1}), net return (₹ ha^{-1}) and B C ratio varied markedly with respect to cropping systems and weed control practices. Among cropping systems, sole linseed recorded lower cost of cultivation than sole chickpea (28,583) and chickpea + linseed (2:1) intercropping, while significantly higher gross return, net return and B C ratio observed in chickpea + linseed (2:1) intercropping than sole linseed and sole chickpea because of in intercropping the equivalent yield of two crops is higher than sole crop due complimentary effect of two crops when they grow under intercropping system. Parallel results were noticed by Rajeshkumar *et al.* (2017) [14] and Meyyappan and Kathiresan (2005) [10]. Among weed control treatments, weed free check noticed higher cost of cultivation because in order to control the weeds manual labours were involved and higher gross return because of higher seed yield but the net return recorded lower because of more cost of cultivation incurred for manual labours and noticed lower cost benefit ratio. Sequential application of pendimethalin 30 EC at 1 kg ha^{-1} as pre-emergent followed by imazethapyr 10 SL at 50 g ha^{-1} as early post emergent at 20 DAS recorded higher cost of cultivation, higher gross return, higher net return and B C ratio compared to only application of pendimethalin 30 EC at 1 kg ha^{-1}, only application of imazethapyr 10% SL at 50 g ha^{-1} (EPoE) at 20 DAS and weedy condition. Parallel results were noticed by Rathod *et al*. (2017) [15] and Devendra *et al.* (2016) [4].

Effect of weed control practices on cropping system parameters

Among cropping systems, chickpea + linseed (2:1) intercropping recorded significantly higher land equivalent ratio, relative crowding coefficient, crop equivalent yield and area time equivalent ratio than sole chickpea and sole linseed because of pure stand of single crop records lower cropping system parameters and also shows better growth and productivity of both the crops. Land equivalent ratio, relative crowding coefficient, crop equivalent yield and area time equivalent ratio varied among different weed control practices. Weed free condition recorded higher land equivalent ratio, relative crowding coefficient, crop equivalent yield and area time equivalent ratio because absence of weeds throughout the crop life cycle. Among herbicidal treatments sequential application of pendimethalin 30 EC at 1 kg ha^{-1} followed by imazethapyr 10 SL at 50 g ha^{-1} at 20 DAS recorded higher land equivalent ratio, relative crowding coefficient, crop equivalent yield and area time equivalent ratio than alone application of pendimethalin 30 EC at 1 kg ha^{-1}, alone application of imazethapyr 10 SL at 50 g ha^{-1} at 20 DAS and Weedy check. Parallel results were observed by Singh *et al.* (2005) [19] and Roy *et al.* (2008) [16].

Table 1: Total weed density of m^{-2} at different crop growth stages of chickpea and linseed as affected by different cropping system and weed control practices

Treatments	Total weed density m^{-2}		
	30 DAS	60 DAS	90 DAS
Main plot (C- Cropping system)			
Sole chickpea	4.78 (22.40)	4.76 (22.20)	4.58 (20.47)
Sole linseed	5.74 (32.53)	5.54 (30.20)	5.23 (26.93)
Chickpea + linseed (2:1 intercropping)	5.07(25.27)	4.80 (22.53)	4.60 (20.73)
S. Em. ±	0.07	0.07	0.10
C. D. at 5%	0.29	0.28	0.39
Sub plots (W- Weed management practices)			
Pendimethalin 30 EC at 1 kg ha^{-1} (PE)	4.86 (23.11)	4.67 (21.33)	4.46 (19.44)
Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS	5.87 (34.00)	5.11 (25.67)	5.20 (26.56)
Pendimethalin 30 EC at 1 kg ha^{-1} (PE) *fb* Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS	4.18 (17.00)	4.46 (19.44)	3.82 (14.11)
Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
Weedy	7.74 (59.56)	7.67 (58.44)	7.34 (53.44)
S. Em. ±	0.07	0.10	0.07
C. D. at 5%	0.21	0.30	0.21
Interaction (C×W)			
S. Em. ±	0.12	0.18	0.12
C. D. at 5%	NS	NS	NS

Transformed values (√x+0.5), figures in the parentheses indicate original values

EC- Emulsifiable Concentrate, DAS- Days after Sowing, PE-pre emergence, EPoE- early post emergence, SL- Soluble liquid.

Table 2: Weed dry weight (g m^{-2}) at different crop growth stages of chickpea and linseed as affected by different cropping system and weed control practices

Treatments	Weed dry weight (g m^{-2})		
	30 DAS	60 DAS	90 DAS
Main plot (C- Cropping system)			
Sole chickpea	3.37 (10.63)	3.79 (13.88)	3.94 (15.04)
Sole linseed	3.81 (14.06)	4.06 (16.04)	4.26 (17.72)
Chickpea + linseed (2:1 intercropping)	3.45 (11.44)	3.94 (15.05)	4.18 (17.02)
S. Em. ±	0.06	0.05	0.05
C. D. at 5%	0.22	0.18	0.20
Sub plots (W- Weed management practices)			
Pendimethalin 30 EC at 1 kg ha^{-1} (PE)	3.57 (12.29)	4.03 (15.74)	4.17 (16.92)
Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS	3.81 (14.09)	4.26 (17.71)	4.39 (18.84)
Pendimethalin 30 EC at 1 kg ha^{-1} (PE) *fb* Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS	2.36 (5.09)	2.83 (7.53)	3.00 (8.53)
Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
Weedy	5.41 (28.74)	5.87 (33.96)	6.26 (38.69)
S. Em. ±	0.07	0.09	0.05
C. D. at 5%	0.20	0.26	0.14
Interaction (C×W)			
S. Em. ±	0.19	0.15	0.08
C. D. at 5%	NS	NS	NS

Transformed values (√x+0.5), figures in the parentheses indicate original values
EC- Emulsifiable Concentrate, DAS- Days after Sowing, PE-pre emergence, EPoE- early post emergence, SL- Soluble liquid.

Table 3: Weed control efficiency (%) and Weed index (%) at different crop growth stages of chickpea and linseed as affected by different cropping system and weed control practices

Treatments	Weed control efficiency (%)			Weed index (%)
	30 DAS	60 DAS	90 DAS	
Main plot (C- Cropping system)				
Sole chickpea	64.50	62.40	57.91	25.84
Sole linseed	58.77	55.69	56.60	25.00
Chickpea + linseed (2:1 intercropping)	62.55	60.18	56.91	25.41
S. Em. ±	1.09	1.04	0.75	1.69
C. D. at 5%	4.26	4.10	NS	NS
Sub plots (W- Weed management practices)				
Pendimethalin 30 EC at 1 kg ha^{-1} (PE)	69.67	59.23	56.29	24.94
Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS	56.32	51.38	51.29	31.69
Pendimethalin 30 EC at 1 kg ha^{-1} (PE) *fb* Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS	83.70	86.51	78.12	13.88
Weed free	100.00	100.00	100.00	0.00
Weedy	0.00	0.00	0.00	58.22
S. Em. ±	1.11	1.37	0.82	1.24
C. D. at 5%	3.25	3.99	2.38	3.62
Interaction (C×W)				
S. Em. ±	1.86	2.22	1.27	2.15
C. D. at 5%	NS	NS	NS	NS

EC- Emulsifiable Concentrate, DAS- Days after Sowing, PE-pre emergence, EPoE- early post emergence, SL- Soluble liquid.

Table 4: Growth and yield parameters of chickpea as affected by cropping system and weed management practices

Treatments	Plant height (cm)	Number of branches $plant^{-1}$	Number of root nodules $plant^{-1}$	Number of pods $plant^{-1}$	Number of seeds pod^{-1}	Test weight (g)
Main plot (C- Cropping system)						
Sole chickpea	32.47	7.43	26.03	41.47	2.05	23.01
Chickpea + linseed (2:1 intercropping)	31.27	7.41	26.73	43.74	2.01	23.65
S. Em. ±	0.16	0.09	0.64	0.43	0.02	0.78
C. D. at 5%	0.37	NS	NS	1.20	NS	NS
Sub plots (W- Weed management practices)						
Pendimethalin 30 EC at 1 kg ha^{-1} (PE)	31.59	7.38	26.23	40.97	2.00	23.27
Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS	31.67	7.23	24.39	35.63	2.07	23.17
Pendimethalin 30 EC at 1 kg ha^{-1} (PE) *fb* Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS	32.37	7.63	21.69	43.37	2.13	22.78
Weed free	33.60	8.07	31.03	45.16	2.13	23.75
Weedy	27.63	6.77	28.54	29.88	1.82	23.33
S. Em. ±	0.88	0.19	0.61	1.04	0.13	0.65
C. D. at 5%	1.87	0.39	1.84	2.21	NS	NS
Interaction (C×W)						
S. Em. ±	1.24	0.26	1.23	1.48	0.19	0.93
C. D. at 5%	NS	NS	NS	NS	NS	NS

Table 5: Growth and yield parameters of linseed as affected by cropping system and weed management practices

Treatments	Plant height (cm)	Number of branches plant^{-1}	Number of capsules plant^{-1}	Number of seeds capsule^{-1}	Test weight (g)
Main plot (C- Cropping system)					
Sole linseed	47.78	4.65	46.60	7.12	5.52
Chickpea + linseed (2:1 intercropping)	48.49	4.66	48.18	7.04	5.57
S. Em. ±	0.20	0.02	0.42	0.14	0.20
C. D. at 5%	0.55	NS	1.20	NS	NS
Sub plots (W- Weed management practices)					
Pendimethalin 30 EC at 1 kg ha^{-1} (PE)	47.35	4.60	44.49	7.33	5.49
Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS	46.37	4.42	42.77	6.70	5.27
Pendimethalin 30 EC at 1 kg ha^{-1} (PE) *fb* Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS	49.10	4.92	51.65	7.46	5.66
Weed free	51.88	5.48	53.68	8.12	5.91
Weedy	44.48	3.86	39.36	5.79	5.40
S. Em. ±	0.49	0.17	0.94	0.15	0.21
C. D. at 5%	1.03	0.35	2.00	0.32	NS
Interaction (C×W)					
S. Em. ±	0.69	0.24	1.33	0.21	0.30
C. D. at 5%	NS	NS	NS	NS	NS

EC- Emulsifiable Concentrate, SL- Soluble liquid, DAS- Days After Sowing, PE-pre emergence, EPoE- early post emergence, *fb*- followed by.

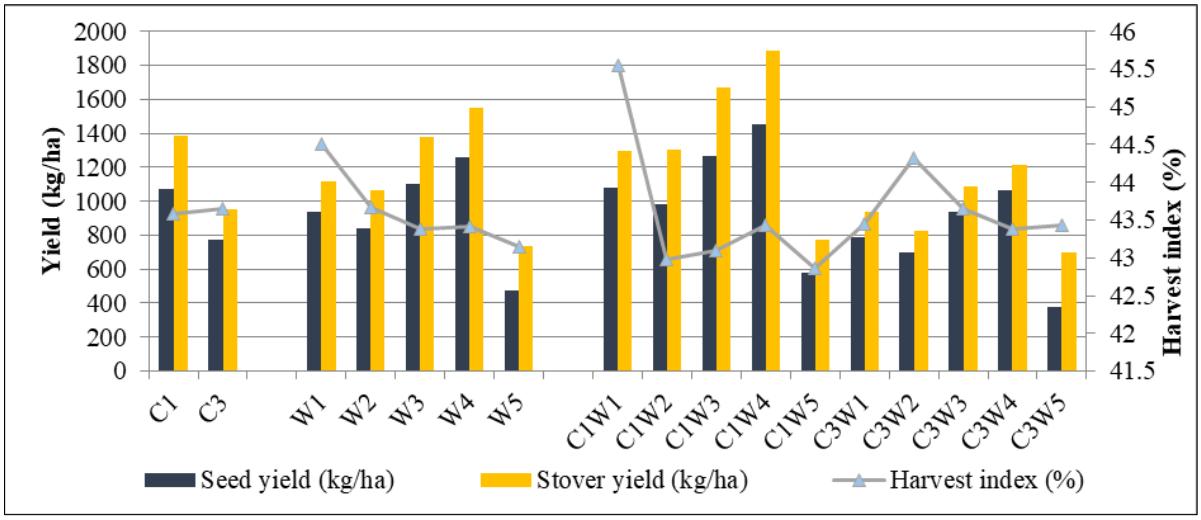
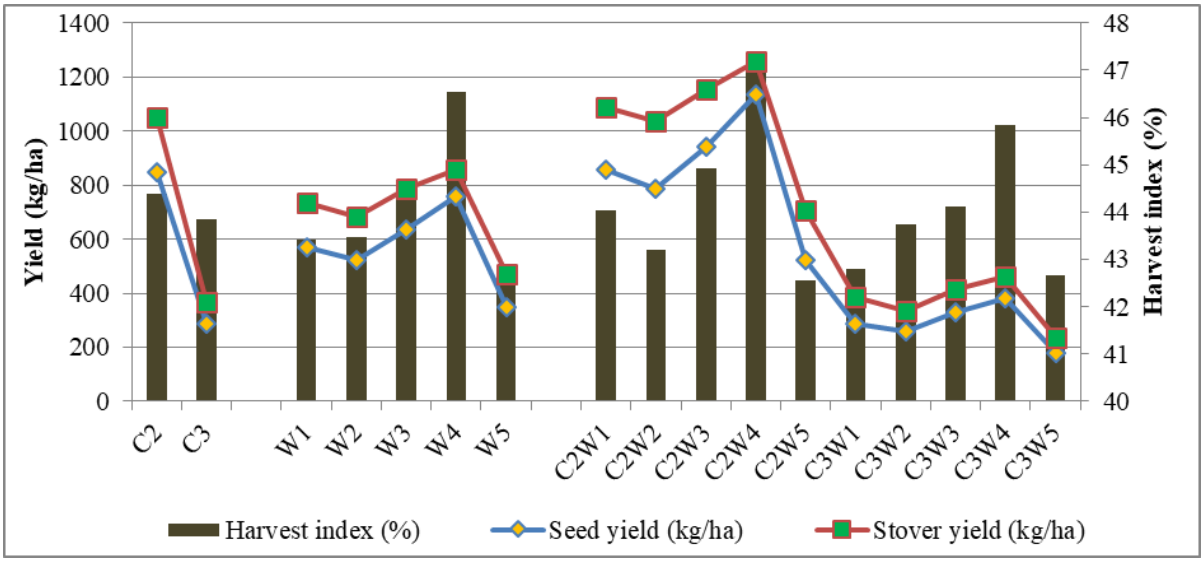


Fig 1: Seed yield, stover yield and harvest index of chickpea as influenced by cropping system and weed management methods



C_1- Sole chickpea, C_2- Sole linseed, C_3- Chickpea + Linseed (2:1) intercropping
W_1- Pendimethalin 30 EC at 1 kg ha^{-1} (PE), W_4- Weed free condition
W_2- Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20DAS W_5- Weedy condition
W_3- Pendimethalin 30 EC at 1 kg ha^{-1} *fb* Imazethapyr 10 SL at 50 g ha^{-1} at 20 DAS

Fig 2: Seed yield, stover yield and harvest index of linseed as influenced by cropping system and weed management methods

Table 6: Cost of cultivation (₹ ha^{-1}), Gross return (₹ ha^{-1}), Net return (₹ ha^{-1}) and B C ratio of chickpea and linseed as affected by different cropping system and weed management practices

Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B-C ratio
Main plot (C- Cropping system)				
Sole chickpea	28583	51468	22885	1.79
Sole linseed	25900	50101	24201	1.93
Chickpea + linseed (2:1 intercropping)	27842	57879	30037	2.05
S. Em. ±	-	419.99	472.18	0.01
C. D. at 5%	-	1649.10	1853.99	0.05
Sub plots (W- Weed management practices)				
Pendimethalin 30 EC at 1 kg ha^{-1} (PE)	25265	53577	28312	2.12
Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS	24097	48531	24434	1.98
Pendimethalin 30 EC at 1 kg ha^{-1} (PE) *fb* Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS	26053	61719	35666	2.40
Weed free	38846	72416	33570	1.85
Weedy	22946	29504	6558	1.28
S. Em. ±	-	899.24	957.83	0.04
C. D. at 5%	-	2624.71	2795.71	0.10
Interaction (C×W)				
S. Em. ±	-	1557.54	1659.01	0.06
C. D. at 5%	-	4546.13	4842.31	0.19

EC- Emulsifiable Concentrate, DAS- Days after Sowing, PE-pre emergence, EPoE- early post emergence, SL- Soluble liquid.

Table 7: Effect of different cropping system and weed control treatments on Land equivalent ratio (LER), Relative crowding coefficient (RCC), Chickpea equivalent yield (CEY) and Area time equivalent ratio (ATER)

Treatments	LER	RCC	CEY (kg ha^{-1})	ATER
Main plot (C- Cropping system)				
Sole chickpea	1.00	1.00	1072.27	1.00
Sole linseed	1.00	1.00	1043.81	1.00
Chickpea + linseed (2:1 intercropping)	1.11	1.29	1126.13	1.04
S. Em. ±	0.01	0.03	8.36	0.01
C. D. at 5%	0.03	0.12	32.82	0.03
Sub plots (W- Weed management practices)				
Pendimethalin 30 EC at 1 kg ha^{-1} (PE)	1.04	1.10	1091.72	1.01
Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS	1.03	1.08	991.25	1.01
Pendimethalin 30 EC at 1 kg ha^{-1} (PE) *fb* Imazethapyr 10 SL at 50 g ha^{-1} (EPoE) at 20 DAS	1.05	1.18	1254.40	1.03
Weed free	1.06	1.16	1460.45	1.03
Weedy	1.01	0.98	605.86	0.99
S. Em. ±	0.01	0.04	18.77	0.01
C. D. at 5%	0.02	0.12	54.77	0.02
Interaction (C×W)				
S. Em. ±	0.02	0.06	32.50	0.02
C. D. at 5%	NS	NS	NS	NS

EC- Emulsifiable Concentrate, DAS- Days after Sowing, PE-pre emergence, EPoE- early post emergence, SL- Soluble liquid.

Conclusion

Based on the results it can be concluded that sequential application of pendimethalin 30 EC at 1 kg ha^{-1} as pre-emergent followed by imazethapyr 10 SL at 50 g ha^{-1} as early post emergent at 20 days after sowing recorded lower weed density, weed dry weight, weed index and higher weed control efficiency, better growth parameters, yield parameters, system parameters, net returns and B C ratio. Similar observations on weed, growth, yield, system and economic parameters were observed in chickpea + linseed (2:1) intercropping than sole cropping.

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