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Validation of the utilization of a specific spray machine to apply general herbicide (Glyphosate) for controlling weeds in chickpea farms in dry land areas of Iran

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ABSTRACT- Weeds are a serious problem of chickpea cultivation in rain-fed areas of Iran and economic feasibility of crop production is mostly challenged by the method of control. In this study, two types of weed control strategies which are common in the country, including hand removing and hand removing + mechanical application, were compared with application of general herbicide (Glyphosite) using a specific spray machine under a minimum tillage system. The trial was carried out in the farms of five ha each, along with a two-ha weedy control at Dry land Agricultural Research Institute (DARI), Maragheh, Iran during cropping season 2018-2019. Chickpea cultivar "Adel" was sown under no - tillage system in planting arrangements of 17.5 × 52.5 cm using a direct drill machine followed by routine operations such as pesticide or fertilizer applications during the growth season. Three patches of 10 m^2 of each treatment were randomly chosen as blocks and measurements were conducted on four randomly chosen 1 m^2 samples as replications inside them. Data arranged as completely randomized blocks design were analyzed. Results showed that although higher yield indices belonged to hand removing or hand removing + mechanical applications, a powerful economic feasibility could be obtained by application of Glyphosate using the spray machine. It may be inferred from this study that in the absence or under situations where application of selective herbicides is non-economic, farmers can apply relatively in-expensive general herbicides to control weeds using this machine and gain acceptable income.

INTRODUCTION

Chickpea (*Cicer arietinum*) is the first most important pulse crop in rain-fed areas of Iran with an annual area grown ranging from 116 – 906 thousand ha during 1978- 2014 (Ahmadi et al., 2015). Iran is regarded as one of the top producers of this crop in the world. Unfortunately, its yield is significantly lower than world average, around 500 kg/ha, due to biotic and abiotic stresses, weeds, lack of cold tolerance cultivars to shift the spring-sowing type of cultivation to the early-winter type, lack of proper mechanization and other economic factors (Pouresmael et al., 2018). In wheat-based agricultural systems of rain-fed areas of Iran where the choice for selection of crops participating in rotation with cereals is very limited, chickpea is always regarded as a valuable option.

Chickpea is inherently assumed as a poor competitor crop with weeds due to slow emergence, slow growth during seedling stage, short stature, open canopy and relatively sparse optimum plant population density, which resulted in excessive weed competition (Al-Thahabi et al., 1994; Blackshaw et al., 2002; McKay et al., 2002; Campbell, 2016). A seed yield reduction of 13- 98% due to weed infestation has been reported from main growing areas in the world (Solh and Pala, 1990; Knot and Halila, 1988; Al-Thahbi et al., 1994; Tanveer et al., 1998; Tiwari et al., 2001; Paolini et al., 2006; Yousefi and Alizadeh, 2006; Frenda et al., 2013). Although different methods are available for controlling weeds in chickpea cultivation, chemical control has attracted more interests due to easy handling, more integrability with other control methods, more efficiency and quick application (Shah et al., 1989; Patel et al., , 2006; Rahman et al., 2012, Chavada et al., 2017; Khan et al., 2018). Pre-plant, pre- and post-emergence herbicides have been tested against chickpea weeds and some of them are reported to be effective, but to date, no highly selective herbicide has been registered for controlling broadleaf weeds in the crop (Baylon et al., 1987; Yasin et al., 1995; Kantar and Elkoca, 1999; Taran et al., 2012; Vasilakoglou et al., 2013; Kumar et al., 2015; Boydston et al., 2017; Jha and Kumar, 2017; Rathod et al., 2017; Rupareliya et al., 2017; Khan et al., 2018; Nath et al., 2018). Management of broadleaf weeds in rain-fed chickpea farms of Iran, especially in minimum tillage forms of conservation agricultural systems, has become a continuous challenge to the farmers. The available registered selective herbicides in the country are very expensive and their application does not have economic feasibility to most farmers. Although manual removal is being carried out in small farms, it is not implacable in large areas. To solve the problem, a specific herbicide spraying machine was designed and manufactured at Dry land Agricultural Research Institute (DARI), Maragheh, Iran, to apply general broadleaf herbicides in chickpea farms. The objective of this research is evaluating this machine in large farm scale and comparing its economic feasibility with conventional weed management techniques.

MATERIALS AND METHODS

The experiment was conducted in 2018-19 cropping season in Maragheh, Iran, at Dry land Agricultural Research Institute's research station (37^o 15' N, 46^o 15' E, 1720 m altitude), with a long-term average perception and temperature of 348.3 mm and 9.4 ^{o}C respectively, as well as with average 128 frosty days in a year. The field on which the experiment was conducted contained clay loam soil, calcic (3-10%), low organic materials (< 0.8 %) and was free of salt and/or alkaline limitations (Feiziasl et al., 2016). Total precipitation at this year was 494.6 mm 66.9% and 33.1% of which took place in the autumn-winter and spring-summer periods, respectively.

Field Set-up and Crop Management

Chickpea cultivar "Adel" was sowed in March 2018 under a wheat-based, no-tillage and conservation system using a direct drill model ASKE-2200 with planting arrangements of 17.5 × 52.5 cm. To gain this arrangement, a brief modification was conducted on the drill (Fig. 1) and a specific tractor speed was regulated (Fig. 2) at the sowing time.

By this alteration, inter-row spacing of 52.5 cm was created between rows to pass the tractor carrying specific herbicide sprayer, whilst the within row spacing of 17.5 cm distance was untouched.

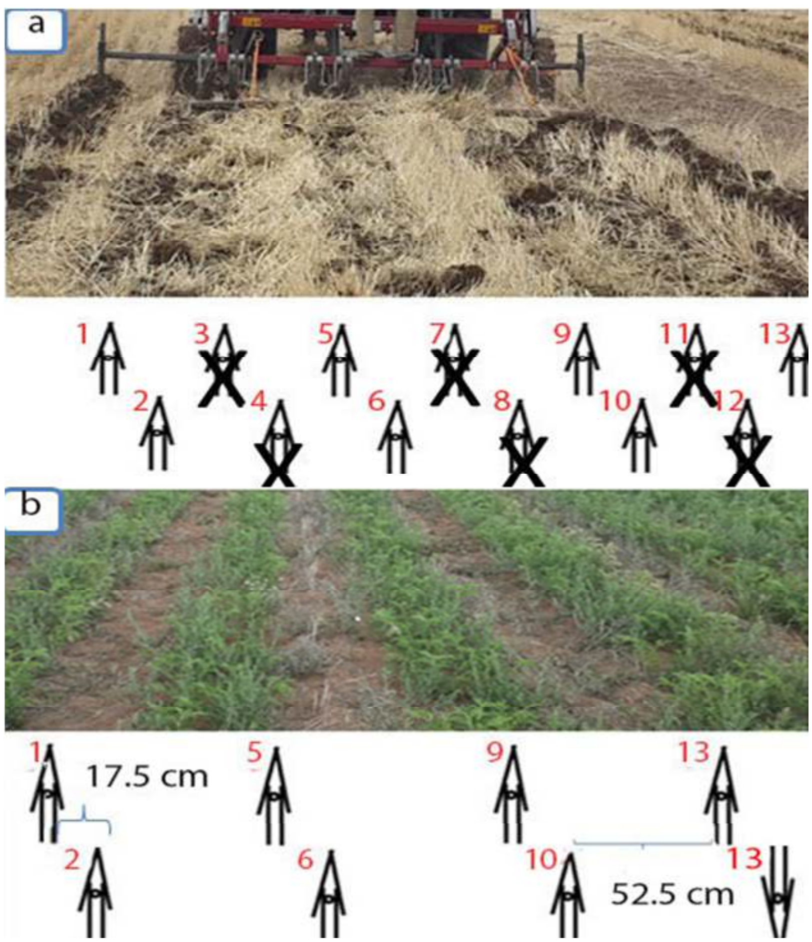

Fig 1. (a) Direct drill model ASKE-2200, which has 13 openers (identified by numbers 1 to 13) to release seeds in the rows of 17.5 cm distance. To establish a seed arrangement to allow tractor and sprayer movement on the ground in the growing season, a minor change was applied on it, which means that (b) seed drill openers numbers 3, 4, 7, 8, 11 and 12 were separated and their relative seed metering's were closed; therefore, the distance between openers number 1-2, 5-6 and 9-10 remained untouched (17.5 cm) while the distance between openers number 2-5, 6-9 and 10-13 shifted to be 17.5×3 = 52.5 cm.

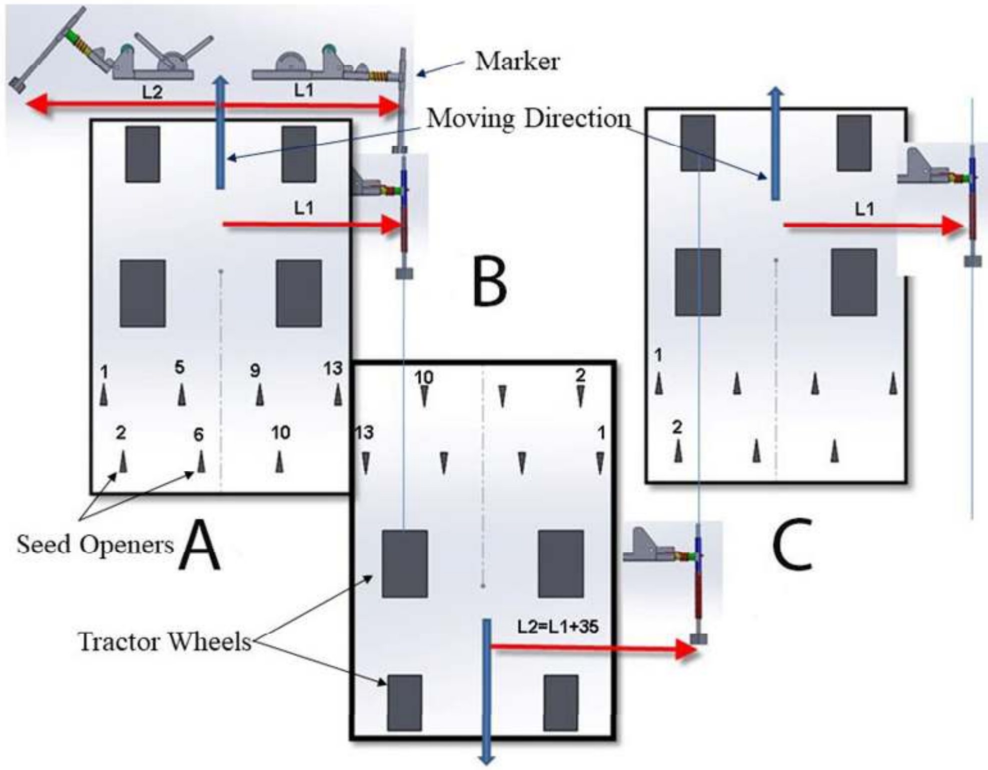

Fig. 2. Schematic drawing of tractor movement along with seed driller in three round trips of sowing operation: (a) in the first run, right hand marker was adjusted at a distance of L1, identifying a trace for tractor wheels for the return; (b) in the second run, the right hand marker was closed and left hand marker (L2) at a distance of L1+ 35 cm was opened instead, to identify wheels movement trace for the third run, while opener number 13 is sowing seeds at a distance of 17.5 cm from the same opener of the first run; (c) in the third round, right hand marker is opened again and the left one is closed while seed opener number 1 was adjusted to the same opener of the second round and is sowing seeds at a distance of 17.5 + 35=52.5 cm.

Our adjustments resulted in a density of 20 seeds m^{-2} and Urea fertilizer at a rate of 15 kg ha^{-1} was applied to the soil as starter at sowing. Furthermore, the non-selective herbicide of Glyphosate (Roundup®) at a rate of 5 liters ha^{-1} was applied immediately after planting to control winter type weeds on all treatments.

A total of 17 ha land was allocated to do this study and weed control treatments were conducted at the 60^{th} day after planting (*dap*) on the four sections of land including: (i) application of a non-selective broadleaf herbicide of Glyphosate using the already devised sprayer (Fig. 3) at the same rate of pre-emergence application between rows, (ii) mechanical control with Rolling cultivator + hand removing after 10 days of application of cultivator in order to get rid of remained weeds on the field, within and between the rows (iii) completely hand removing, within and between the rows, and (iv) without any weed control (check). Treatments 1-3 and 4 were conducted in 5 and 2 ha lands, respectively.

Sampling and Data Collection

Three patches of the land, each of 10 m^2, were randomly chosen as a block inside each treatment section. The measurements were performed in July 2019 with harvesting of four randomly chosen 1m^2 area (containing 20 plants) as a replication after removing marginal effects. Subsequently, chickpea bushes were pulled out of the roots, seeds were seperated from pods manually and finally the grain yield, stubble weight, weight of 100 seeds, plant height, height of the first pod above ground and the number of pods per plant were calculated in kg ha^{-1} or per unit area of one square meter, accordingly.

Weed species were identified using regular keys after sampling at the flowering stage and dried in the laboratory within paper layers. Weed density was determined simultaneously during the growing season using a quadrat of one square meter, and was positioned randomly three times onto different points of each block.

Economics

Gross and net returns were calculated; moreover, fixed and variable costs of different treatments were estimated in order to compare economic features of each weed management system. Total income was calculated by multiplying crop yield by price for three different expected sale values in ± 10% domains.

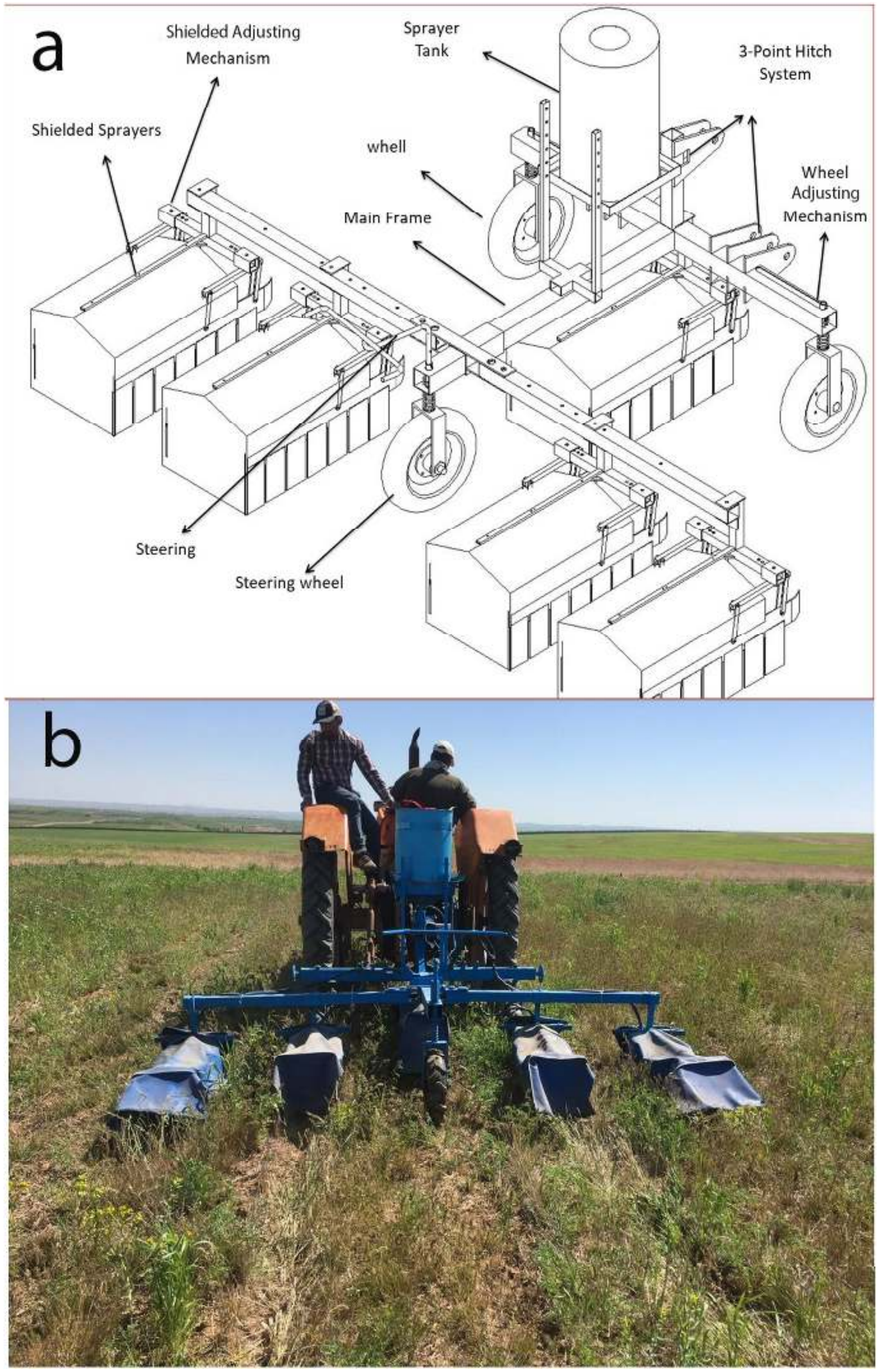

Fig. 3. Sprayer machine developed in Dry land Agricultural Research Institute used for chemical control of chickpea weeds in the current study; (a) the spray machine consisted of eleven main components including (i) main frame, (ii) shield sprayers, (iii) a 50 L sprayer tank, (iv) the nozzles powered by (v) a seven-volt battery, and (vi) a three-wheel carriage. The side wheels move in direct way while the central one could move freely (vii) steering unit to operate manually as well as by tractors through (viii) three-point hitch-system. Moreover, (ix) wheel adjusting system was used to move the sprayer in any plant row distance in the field. Five units of shielded sprayers contained (x) shielded adjusting mechanism which was constructed to regulate working width and was connected to the main frame, which means the machine could be used for working in any plant arrangement in the field. The spraying liquid was delivered to nozzles through (xi) plastic tubes, inside which the liquid flow was supplied only by gravity; (b) sprryer machine working in the field.

Statistical Analyses

Data was subjected to a completely randomized block design and ANOVA was performed using STATISTIX ver. 10 (Analytical software, Tallahassee, USA) after transformation by log $_x$ + 1 prior to the analysis, to ensure normal distribution. Treatment means were compared with Tukey's multiple comparison test at 0.05 probability level.

REULTS AND DISCUSSION

Plant Population

Results showed that the plant population were 18 spices which belonged to 12 different families, where *Asteraceae* and *Bracicaceae* which had four species were dominant plant families in the field. Moreover, only four species were perennial and the majority (77.7%) had an annual life style. The most density was observed for Common Knapweed (*Centaurea despressa*), followed by Russian Knapwood (*Acroptilon repence*) and False Carrot (*Turgenia latifolia*) (Table 1). Annual broadleaf weeds constituted the majority of weed population in this study, which is in harmony with previous observations carried out on weed community of the crop in Iran (Abbasian et al., 2016; Fathi et al., 2016; Nosrati et al., 2017).

Methods of Weed Control

Treatments including non-selective herbicide application, mechanical control + hand weeding, completely hand weeding and weedy check showed a significant difference at *P* value of < 0.01 (Table 2).

Plant height and first pod distance from ground ranged between 29.4 – 43.3 and 19.55 – 29.95 cm, while 100 seeds weight, straw weight and yield ranged between 21.48 – 29.18, 580.00 – 1270.00 gr and 150.00 – 920.00 kg. ha^{-1}, respectively. The number of pods per plant showed maximum and minimum values of 7.60 and 24.50, respectively (Figs. 4, a-e).

Plant height is assumed as one of the most important physiological factors negatively affected by competition with weeds in all crops (Kropff, 1988; Rathod et al., 2017). In the current investigation, the highest plant height was attained in herbicide application treatments (Fig. 5-a). Gaining the highest plant height by application of non-selective chemicals using this method is undoubtedly resulted from complete eradication of competitor weeds, or at least, minimizing their negative competition effects. No clear relationship was found between the first pod insertion and any weed control treatment, which is in harmony with previous studies (Avola et al., 2008).

Table 1. Weed species and their density in the experimental chickpea field during 2017-18

Botanical Name	Persian Name	Common Name	Life Cycle	Average Number Per Plot
Acroptilon repens (Asteraceae)	تلخه (Talkheh)	Russian Knapwood	P†	23
Adonis aestivalis (Ranunculaceae)	چشم خروس (Cheshm-e-Khrous)	Pheasant's Eye	A	2
Cardaria draba (Brasicaceae)	اوزمک (Uzmak)	Hoary Cress	A	4
Centaurea depressa (Asteraceae)	گل مریم (Gol-e-Maryam)	Common Knapweed	A	69
Circium arvense (Asteraceae)	کنگر وحشی (Kangar-e-Vahshi)	Canada Thistle	P	5
Convolvulus arvensis (Convulvulaceae)	پیچک (Pichak)	Field Bindweed	P	5
Erysimum repandum (Brassicaceae)	خاک شیر بدل (Khak Shir-e-Badal)	Bushy Wallflower	A	4
Fumaria officinalis (Fumariaceae)	شاه تره (Shah Tareh)	Earth Smoke	A	3
Galium aparine (Rubiaceae)	بی تی راخ (Bi Ti Rakh)	Goosegrass	A	4
Geranium molle (Geraniaceae)	شمعدانی وحشی (Sham'adani-e-Vahshi)	Dovesfoot Geranium	A	5
Goldbachia laevigata (Brassicaceae)	ناخنک (Nakhonak)		A	2
Hypecoum pendulum (Papaveraceae)	زرد شاه تره(Zard Shah Tareh)	Nodding Hypecoum	A	17
Lisaea heterocarpa (Apiaceae)	فلفلی (Felfeli)		A	2
Muscari comosum (Asparagaceae)	کلاغک (Kalaghak)	Tassel Hyacinth	P	4
Raphanus raphanistrum(Bracicaceae)	تربچه وحشی (Torobche-Vahshi)	Wild Radish	A	3
Silene conoidea (Caryophllacea)	گندمک (Gandomak)	Weed Silene	A	3
Tragopogon graminifolius (Asteraceae)	شنگ *(Sheng)*	*Goatsbeard*	A	5
Turgenia latifolia (Apiaceae)	ماستونک (Mastunak)	False Carrot	A	19

†: A and P are Annual and Perennial, respectively

Table 2. Analysis of variance for yield components of chickpea production under different modes of weed control

Source	DF	Mean Squares (MS)					
		Plant Height	First Pod Distance from Ground	100 Seed Weight	Weight Straw	Yield	No. Pods/Plant
Block	2	0.0014	0.00587*	0.0020**	0.01647	0.0552**	0.0019
REP	3	0.0002	0.00014	0.0005	0.00867	0.0113	0.0052
Treatment	3	0.0006**	0.01387**	0.0063**	0.17178**	0.4769**	0.5444**
Error	39	0.0008	0.00135	0.0003	0.00518	0.0077	0.0105
CV%		1.89	2.69	1.37	2.38	3.22	1.0564

*and ** are significant at $P < 0.5$ and $P < 0.01$, respectively.

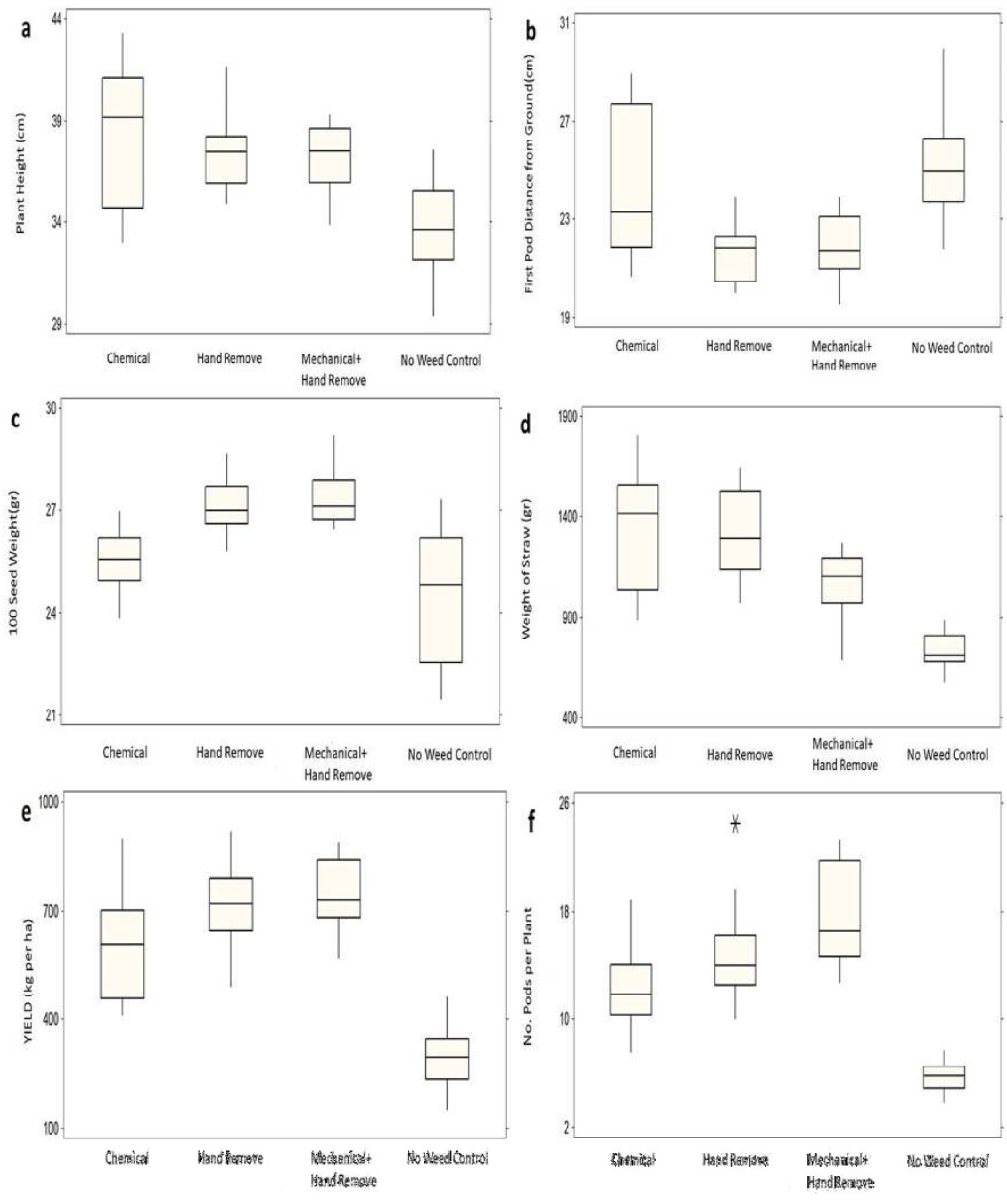

Fig. 4. Box plots showing distribution of chickpea cultivar Adel's plant height (a), first pod destination from ground (b), 100 seeds weight (c), weight of straw (d), yield (e) and number of pods per plant (f) measured at three different weed control methods and a non-controlled treatment.

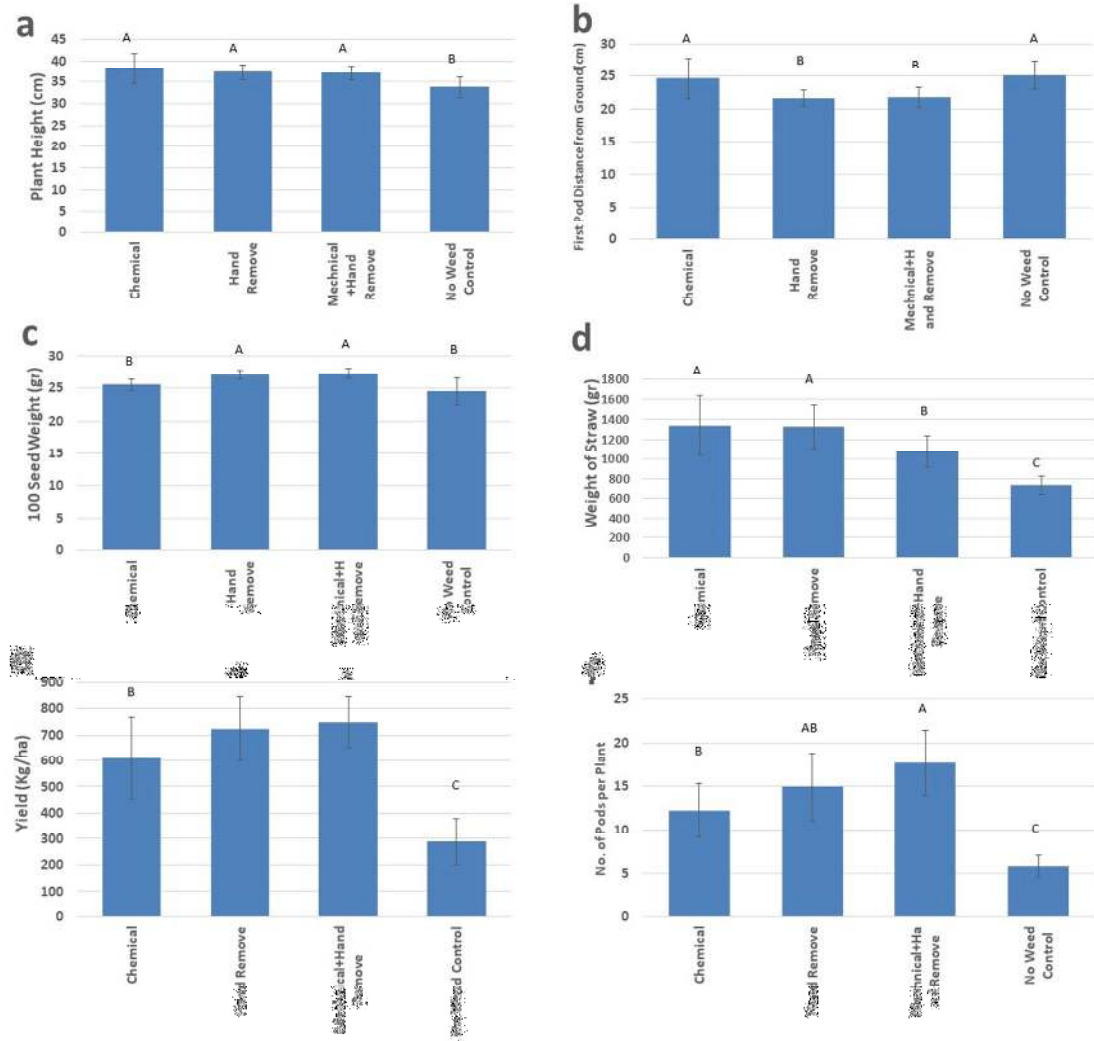

Fig. 5. Mean of chickpea cultivar Adel's plant height (a), first pod destination from ground (b), 100 seeds weight (c), weight of straw (d), yield (e) and number of pods per plant (f) measured at three different weed control methods and a non-controlled treatment. Vertical lines and different letters represent standard deviations and significant differences ($p < .05$), respectively

100 seeds weight was significantly influenced by weed management practices where the highest amount was achieved by completely hand removing and mechanical + hand removing treatments (Fig. 5, c). These treatments led to the complete removal of weeds from plots while weedy check produced the lowest amount of seed weight, which is in agreement with Merga and Alemu (2019) and Mekonnen et al. (2015).

Different weed management led to obtaining different patterns of biomass production. Chemical application and hand removing treatments produced the highest weight of straw in the experimental plots while the lowest amount was obtained in weedy check (Fig. 5, d). Higher amounts of above-ground biomass in chemical application due to more efficient utilizing of resources by the plant has been reported in previous studies (Plew et al., 1994; Merga and Alemu, 2019).

Seed yield and number of pods per plant in the weedy control treatment showed the lowest values compared with different weed managements, which is in agreement with Merga and Alemu (2019) and Rathod et al. (2017). The highest value of seed yield and number of pods per plant was obtained in the treatments containing hand removal of the crop, in contrary, the herbicide application produced lower amounts of these indexes (Fig. 5, e - f).

Economics

Results showed that mechanical + hand removal, and chemical treatments had the highest and lowest production costs, respectively. Although these treatments gained higher gross returns compared with other weed management systems, the chemical application showed the highest net return for all three expected sale values (Table 3).

The higher gross returns achieved for hand removal and hand removal + mechanical practices are mainly attributed to the higher yield indices (Fig. 5, c, d, e) while in chemical application, the net returns increased significantly due to lowering expenditures, especially labor cost which is a vitally important factor in crop production in the country.

Table 3. Total cost and net gross income for three different expected sale values

Treatment	Total Cost (Million Rials)	Expected Sale Values ±10% (Rials kg^{-1})		
		45,000	5,000	55,000
Chemical	11.194	2.98	2.80	2.68
Hand Removing + Mechanical	22.654	1.80	1.95	2.04
Hand Removing	21.754	2.18	2.26	2.32
Weedy Check	7.554	1	1	1

CONCLUSIONS

Weeds are a major problem in chickpea cropping systems in Iran and weed control is principally achieved by hand removal. Although a number of selective or semi-selective herbicides have been introduced in recent years, their application in the chickpea farms of Iran is very limited due to lack of economic feasibility. In the current study, we introduced a specific spraying machine able to apply general herbicides (Glyphosate) in the chickpea farms although success in its application depends on establishing a very precise plant arrangement. It was accomplished by a significant alteration in drill machine. Consequently, we validated its application through an experimental trial where yield indices for the crop using chemicals were compared to yield indices of crop using other methods of weed control. Fortunately, results showed its clear economic advantage over traditional approaches which is undoubtedly achieved through acceptable yield indices. Furthermore, application of chemicals limited to the plant rows led to the reduction of water usage (around 40%), compared to spraying all field in the conventional methods. This could have a further economic feasibility as well as an eco-friendly feature for this machine. Lower use of harmful chemicals is another significant advantage of the proposed method.

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اعتبارسنجی استفاده از ماشین پاششی ویژه برای کاربرد علف کش عمومی (گلایفوسیت) به منظور کنترل علف‌های هرز مزارع نخود در مناطق دیم ایران

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واژه‌های کلیدی:
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چکیده- علف‌های هرز یکی از مشکل‌های اصلی کشت و کار نخود در دیمزارهای ایران بوده و صرفه اقتصادی تولید تا حد زیادی وابسته به نحوه ی کنترل آنهاست. در این پژوهش، روش‌های عمده‌ی مبارزه با علف‌های‌هرز که در کشور رواج دارد؛ شامل وجین دستی و کنترل مکانیکی + وجین دستی، با کاربرد یک علف کش عمومی (گلایفوسیت) با استفاده از یک ماشین پاششی مخصوص در یک سیستم بدون خاک‌ورزی مقایسه گردید. آزمایش در مزارع آزمایشی پنج هکتاری همراه با یک مزرعه دو هکتاری شاهد بدون مبارزه با علف‌هرز در طی سال زراعی ۹۷-۱۳۹۶ در اراضی مؤسسه تحقیقات کشاورزی دیم کشور (مراغه) انجام گرفت. نخود رقم عادل در یک آرایش کشت ۱۷/۵ × ۵۲/۵ سانتی‌متری با استفاده از یک دستگاه کارنده‌ی مستقیم کشت گردید و عملیات رایج زراعی مانند مبارزه با آفات و کوددهی در طی فصل رشد انجام شد. سه تکه زمین ۱۰ مترمربعی در داخل هر تیمار بصورت کاملاً تصادفی انتخاب شده و به عنوان بلوک فرض شدند و کلیه اندازه‌گیریها در داخل چهار نمونه‌ی یک مترمربعی که کاملاً تصادفی و به عنوان تکرار انتخاب شده بودند، در داخل این تکه‌های ده مترمربعی انجام گرفت و سپس داده‌ها در قالب طرح بلوک‌های کامل تصادفی تجزیه شدند. نتایج نشان دادند که اگرچه وجین دستی و کنترل مکانیکی + وجین دستی دارای بالاترین شاخص های عملکرد هستند، اما بیشترین توجیه اقتصادیِ کنترل متعلق به کاربرد علف‌کش عمومی گلایفوسیت با استفاده از ماشین پاششی ویژه بود. این نشان داد که تحت شرایطی که کاربرد علف‌کش های انتخابی به دلیل گرانی و کمبود در بازار غیر اقتصادی است، کشاورزان نخود کار می‌توانند با استفاده از این دستگاه، علف‌کش‌های عمومی نسبتاً ارزان را برای کنترل علف‌های‌هرز به‌کار برده و درآمد قابل قبولی را بدست بیاورند.