IMPACT OF WHEAT (*TRITICUM AESTIVUM* L.) SEED CLEANING, HERBICIDES, AND THEIR INTERACTIONS ON WEED CONTROL, YIELD, AND YIELD COMPONENTS IN TWO DIFFERENT LOCATIONS

HORAMANI, K. F. M.[1*] – SARMAMY, A. O. I.[2]

[1]*Biotechnology and Crop Sciences Department, College of Agricultural Engineering Sciences, University of Sulaimani, Sulaimani, Kurdistan Region, Iraq*

[2]*Biology Department, College of Science, University of Salahaddin, Erbil, Kurdistan Region, Iraq*

**Corresponding author*
e-mail: kawa.mustafa@univsul.edu.iq

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Abstract. A factorial experiment (2 × 5) was applied according to Randomized Complete Block Design (RCBD) with four replications in two different locations, Qlyasan and Kani Panka in Sulaimani Governorate, Kurdistan Region of Iraq, during the winter season of 2018-2019. The objectives were to determine the effects of wheat (*Triticum aestivum* L.) seed cleaning (factor 1), weed control treatments (factor 2) and their interactions on weed control, wheat yield and yield components at two different locations. Seed cleaning decreased weed dry weight and increased number of spikes m^{-2}, number of grains $spike^{-1}$, weight of 1000 grains, grain yield m^{-2} and weed control efficiency significantly. Hand weeding and herbicides mixture decreased weed dry weight and increased grain yield.m^{-2} with some yield parameters, and weed control efficiency significantly. The interactions between locations and seed cleaning decreased weed dry weight, and increased grain yield and yield components and weed control efficiency significantly. Interactions between seed cleaning and weed control treatments decreased weed dry weight and increased grain yield m^{-2}, yield components, and weed control efficiency significantly. The triple interactions between locations, seed cleaning and herbicide mixture decreased weed dry weight and increased number of spikes m^{-2} 1000 grains weight, grain yield m^{-2} (6.36 $t.ha^{-1}$) and weed control efficiency significantly.
Keywords: *crop production, cleaning machinery, grain weight, clodinafop-propargyl, Granstar*

Introduction

Wheat (*Triticum aestivum* L.) is of prime importance in the kingdom of food crops standing second globally in terms of grain production and is the most widely cultivated food crop followed by rice, maize, sorghum and pearl millet. The total area of the world under wheat cultivation is around 220.5 million ha with a grain yield of 760.4 million tons, and an average wheat yield of 3.45 ton ha^{-1} (FAO, 2019).

Wheat production in Iraq is 5.1 million tons in over a total cultivated land of 2.12 million ha (FAO, 2014). In Kurdistan Region wheat fields occupy 567627 ha, which represents the largest acreage crop there, covering about 78% of rain-fed area (Al-Najafi, 1989), which has produced about 500000 tons during 2015, with an average wheat yield of about 0.88 ton ha^{-1}, this figure is very low comparing to the international average grain yield (only 25%), but there is potential opportunity to improve it significantly (Mazid, 2015). Weeds are a perennial problem for farmers; they are considered one of the important factors limiting crop production. Weeds are widely spread and reduce yield of crops considerably. Weeds also lower crop quality and may reduce the protein content of the grain (Monaco et al., 2002). Among the biotic factors weeds are one of the major constraints in wheat production as they reduce productivity due to competition,

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allelopathy and by providing proper habitats for pathogens as well as serving as alternate host for various insects, fungi and increase harvest cost (Ayana, 2019).

Farmers spend a lot of resources to reduce weeds impact, many a times quite unsuccessfully (ISWS, 2018). It is estimated that losses caused by weeds for wheat production ranges between 29 to 31% (Oerke, 2006; Gharde et al., 2018) while other studies mentioned that this figure may reach to 65% (Amare et al., 2014).

From the beginning of agriculture until the introduction of herbicides, weed management in agriculture depends largely on crop rotation, tillage, and seed cleaning. But the heavy reliance on chemical weed control is nowadays considered nonacceptable or not good enough (Das, 2008), this is mainly due to extensive use of chemicals with potential destructive side effects on food safety, public health, and the environment. Cropping systems focusing on using herbicides for weed control are becoming progressively at risk, as herbicide resistance are considerably creating situations where some weed species cannot be controlled by chemical methods (Kumar, 2014).

Weed control is becoming harder due to economic expenses of weed control; the elevating herbicidal prices; higher yield demands; economic and political factors. Unethical use of herbicides causes serious damage not only to the crop but even to the agro-environment. Misuse of herbicides increases herbicide resistance weed plants, soil and irrigation water contamination eventually causes killing of non-target organisms which might alter the natural balance of the area (Labrada et al., 1994).

Also frequent using of herbicides produce weed resistance to herbicides, therefore, to minimize this problem and for efficient weed management, by applying non-chemical weed management tactics or by reducing herbicide applications such as cleaned or weed-free cultivated seeds should be adopted in conjunction with chemicals (like herbicide mixture and rotation, optimum spray time, dose, and methods) (Chicouene, 2020; Norsworthy et al., 2012) or through minimizing herbicides amount. Some of the non-chemical agronomic strategies like tillage, sowing time and methods, competitive crop cultivars, higher crop density, crop rotation and sanitation practices (weed-free crop seeds and seed cleaning) can be adjusted and adopted in such a manner that they provide the competitive edge to the crop over weeds (Owen and Powles, 2020; Hossain, 2015; Michael et al., 2010). Several studies have found that cleaning the seeds reduces the return of weed seeds to the soil and increases wheat grain yield (Lollato et al., 2020; Burkov et al., 2018; Norsworthy et al., 2012; Walker, 1995).

The project’s objectives are to determine the effect of seed cleaning on wheat crop yield and yield components, and to compare these results with the traditional method of weed control by herbicides or hand weeding to determine whether seed cleaning could replace or minimize the use of herbicides in wheat fields.

Materials and methods

Experimental design and land preparation

Field experiments were carried out at two locations; Qlyasan Research Station/College of Agricultural Engineering Sciences/University of Sulaimani (coordination 35°34’18”N, 45°22’01”E with altitude of 749 m asl) and Kani Panka Agricultural Research Station/Ministry of Agriculture/Kurdistan Regional Government (coordination 35°22’27.35”N, 45°43’02.48”E with altitude of 540 m asl), 40 Km south east of Sulaimani city, Kurdistan region/Iraq (*Fig. 1*).

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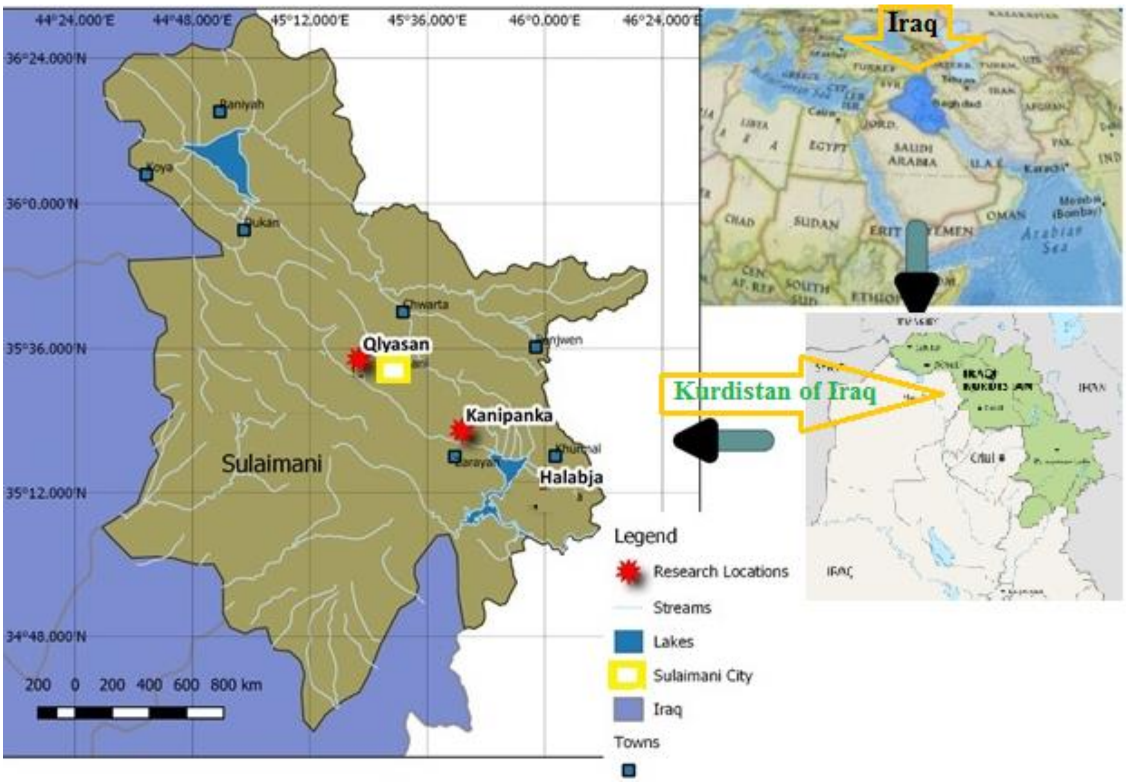

Figure 1. *Map of Sulaimanie governorate (Kurdistan region/Iraq) explaining field site locations*

A combined experiment was applied using Two ways-ANOVA randomized complete block design (RCBD) with four replications. Two factors were tested, the first factor was wheat seeds with two treatments: cleaned seeds, that were cleaned by seed cleaning machine after harvesting by the combine harvester to get rid of any weed seeds, infested seeds by insects or fungus, debris, dirt, dust, immature seeds, empty seeds, shrunken seeds, discolored seeds, peeled or broken seeds; and Non-clean seeds, which in this treatment wheat seeds left without cleaning after harvesting by the combine harvester. The second factor was herbicide application at five levels: Control: no herbicide and no methods of weed control was used; hand weeding for one time; narrow leaved herbicide (Topic); broad leaved herbicide (Granstar); and mixture of both herbicides (Topic + Granstar).

Qlyasan and Kani Panka lands were cultivated on 14/11/2018 and 15/11/2018 respectively, by moldboard plow and treated with disk harrows. Land area allocated in each site was 527 m^2, divided into four blocks, each block consisted of ten plots 2 × 3 m (6 m^2), 1 m was left between plots in all directions to avoid seepage between them, plots were divided into 15 rows by a handy tool, space between rows was 20 cm and rows length was 2 m. Rows were vertical on ground slope.

Cleaning and sowing wheat seeds

Wheat seeds (var. Adana) were collected from the fields of College of Agricultural Engineering Sciences, harvested by the combine harvester during June 2018. Those seeds were divided into two parts; the first part was used in the experiments of this

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study as clean seeds which was cleaned by the seed cleaning machine (Agrosaw mobile seed cleaning machine) to get rid of any weed seeds, infested wheat seeds by insects or fungus, debris, dirt, dust, immature seeds, empty seeds, shrunken seeds, discolored seeds and peeled or broken seeds. But the second part not cleaned seeds were harvested by the combine harvester without cleaning.

Wheat seeds (cleaned and non-cleaned) were sown at a rate of 120 kg ha^{-1} (which means 72 g. $plot^{-1}$ or 4.8 $g.row^{-1}$) in both Qlyasan and Kani Panka locations on 22/11/2018 and 29/11/2018 respectively. For the cleaned seeds number of seeds per row was 120 seed for each 4.8 gram, but for uncleaned seeds the weight was the measurement method due to containing many other bodies such as weed seeds, empty or broken seeds, debris and other materials that are similar in size to wheat seeds.

Cultural practices were conducted normally including fertilizing with di-ammonium phosphate (DAP 18-46) which was applied in all treatments with cultivation, in a dose of 174 kg ha^{-1}, while urea (46% N) was applied in a dose of 106 kg ha^{-1}, divided into two parts, the first part was applied in tillering stage and the second application was in booting stage for both locations.

Weed control treatments by herbicides application

Herbicides were applied using spray method. Knapsack sprayer was prepared to be calibrated after filling with water, sprayed on area of four treatment unites ($4 \times 6 = 24\ m^2$) till complete wetting of all plants, the amount of water used was calculated to be 0.5 L, calculations of herbicide solution were made upon 200 L solution for 1 ha.

On 24 Jan 2019 and 30 Jan 2019 herbicide applications were done in Qlyasan and Kanipanka respectively in calm warm days (*Table 1*).

Table 1. *Monthly temperature and precipitation for Qlyasan and Kani Panka for the season 2018-2019*

Months		Qlyasan				Kani Panka			
		Min. temp. (°C)	**Max. temp. (°C)**	**Avg. temp. (°C)**	**Rainfall (mm)**	**Min. temp. (°C)**	**Max. temp. (°C)**	**Avg. temp. (°C)**	**Rainfall (mm)**
2018	October	10.8	36	23	41.5	9.7	34.3	22	27
	November	5	25.9	15.4	101	4.2	24.5	14.4	114.5
	December	2.3	18	10.1	324	3.1	17	10.5	328.4
2019	January	-2.5	15	6.5	152	-1.2	15.18	7	155.6
	February	1.5	17	9.2	135	2.4	13.3	7.8	153
	March	1.6	19.5	10.5	266	2	16	9	170
	April	5.5	26	15.7	177	7	23	15	120
	May	10.4	36	18.2	44.1	11	34	22.5	22
	June	21.6	42	32	4.6	19	38	29	2
Total rainfall					1245				1093

Water table level was measured for both locations, through nearest existing wells on the experiments land, using a sounder instrument electrical measuring tape, it was found

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that water table in Qlyasan is 22 m, while in Kani Panka it was 14 m from the earth surface. Plot controls were left without treating by any herbicides or weeding activities.

Hand weeding

Hand weeding treatment have been done for plots of cleaned and non-cleaned seeds for Qlyasan and Kanipanka on 4th and 7th March, 2019 respectively, in which all weed plants were cut above ground and classified in the laboratory to narrow and broad leaf weeds, fresh weights of weed plants was measured, then all weeds were kept in punched paper bags and dried in the oven on 70 °C, for 72 h, dry weight of narrow and broad leaf weeds was also calculated.

Topic 080 EC herbicide

Topic 080 EC herbicide (clodinafop-propargyl $C_{17}H_{13}ClFNO_4$) (FAO, 2010) was applied to control narrow leaved weeds in wheat fields. Topic 080 EC is an emulsion, that can be mixed with water and other herbicides, clodinafop-propergyl inhibits acetyl co-enzyme A carboxylase and belongs to the aryloxy phenoxy propionate family, Topik herbicides are taken up by foliage and are translocated via the phloem to areas of new growth accumulate in the tips (meristems), which is the site of action, as a results cell division and elongation are stopped , resulting weak and stunted plants of susceptible treated weeds (Ali et al., 2016; Cavanaugh et al., 1998). The recommended amount of Topic herbicide to control narrow leaved weeds in wheat fields is 0.8 L. ha^{-1}, which is also equal to 0.8 L/200 L of water for 1 ha.

Five liters of water was powered into the knapsack tank with 40 cc of Topic herbicide and the solution volume was completed to 10 L by tap water. Metal land marks for treatment units were fixed on the ground according to field map (in each replication two marks were used, one treatment unit for cleaned seeds and another unit for non-cleaned seeds), spray was done from 30 cm height ensuring all plants inside treatment unit were equally receiving herbicide solution.

Calculations for herbicide application were as follows:

$$\frac{0.8\ \textit{Liter herbicide}}{\textit{one hectare of land}} = \frac{0.8\ \textit{Liter herbicide}}{200\ \textit{liter of water}}$$

$$\frac{800\ \textit{cc herbicide}}{200\ \textit{liter of water}} = \frac{40\ \textit{cc herbicide}}{10\ \textit{liter of water}}$$

Granstar herbicide

Granstar (75% tribenuron methyl $C_{15}H_{17}N_5O_6S$ + 25% inert) is an herbicide used to control broad leaf weeds as post emergence in wheat fields (Mukherjee et al., 2015), Granstar is a member of sulfonyl urea family, a selective and translocated herbicide that is absorbed through the leaves to the meristematic tissues, which can move via the phloem to all parts of the plant, and inhibit amino acid synthesis namely, acetolactate synthase enzyme (ALS ase) to prevent the production of specific amino acids, the key building blocks for normal plant growth and development (Haghighi et al., 2019; Baghestani et al., 2007), the trade formula is granular dissolve in water , meanwhile capable to be mixed with other herbicides. Two grams of granular formula of Granstar herbicide was dissolved in 5 L of water in the Knapsack tank and the solution was completed with tap water to 10 L. The spray operation was done as in Topic herbicide application.

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Herbicide mixture (Topic + Granstar)

For the herbicide mixture treatments, the same amount of Topic and Granstar herbicides (as mentioned above) were poured into the knapsack tank containing 10 L of water, mixed well and sprayed.

Studied characters of wheat

On 1st and 3rd June 2019 Kanipanka and Qlyasan experiment fields were harvested respectively, 1 m^2 in the center of each treatment unit was harvested, all plants above ground were collected for each experiment unit and kept in labeled plastic bags. Bags were transferred immediately to the laboratory; wheat plants were separated from weed plants. *Tables 3* and *4* illustrate weed plants that still exist (as dry or fresh status) with wheat plants, during harvest period, in both fields of Qlyasan and Kanipanka.
The following parameters were registered for all harvested wheat plants:

Dry weight of weed plants

Weeds enclosed within 1 m^2 harvested from each plot were separated from the wheat plants, weeds were dried easily due to the high temperatures during harvest period in June, in addition to the low relative humidity. The dry weights obtained were expressed in $g.m^{-2}$.

Number of spikes m^{-2}

Spikes were counted in an area of 1 m^2 of the harvested wheat in each plot.

Number of kernels (grains) spike^{-1}

Ten spikes of wheat plants were taken randomly from 1 m^2 of the harvested plot, thrashed manually, grains were separated from straw and counted using electrical grain counter, then averaged to get the number of grains spike^{-1}.

Grain weight (1000 grains)

One thousand grains were counted from representative samples of each treatment drawn from winnowed and cleaned produce, and their weight in grams was determined.

Grain yield m^{-2}

All wheat spikes of 1 m^2 of the harvested plots were thrashed manually, grains were separated from straw and weighed.

Statistical analysis

Statistical analysis for all measured variables was performed using the XLSTAT software (XLSTAT, 2016). For direct comparison of treatments, least significant difference tests (LSD) at level of 0.05 was used, and the data were subjected to analysis of variance (ANOVA).

Preparation of soil samples and soil analysis

Soil samples of both experimental locations Qlyasan and Kanipanka were taken using an auger at a depth of 0-30 cm from the soil surface. Subsamples taken from

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Qlyasan location were mixed carefully, then a representative sample soil free from plant roots and other debris, was gently air dried, crushed, and sieved using a 2 mm stainless steel sieve, then the sample was taken for physical and chemical analysis. Particle size distribution for textural class assessing was carried out by international pipette method as described by Black et al. (1965).

Hydrogen ion concentration (pH) and electrical conductivity (EC) were measured in a suspension ratio of 1:10, soil to H_2O as determined by Gupta (2004), using pH model of WTW 330i, whereas for EC the model WTW 330i EC-meter was used.

Organic matter percentage (O.M.%) were determined by wet oxidation method according to Walkley-Black method (Black et al., 1965). O.M. % was calculated according to the following equation:

$$\text{O.M. \%} = \text{Organic carbon\%} \times 1.724 \text{ (factor)}$$

Calcium carbonate $CaCO_3$% (g kg^{-1}) was determined according to a 23C method of U.S. Salinity Laboratory Staff, 1954, as mentioned in Black et al. (1965) water table level was measured for each location through measuring the water level in the wells of each land using a geotech water level meter (*Table 2*).

Table 2. *Physical and chemical properties of the soil samples for experimental locations (Kanipanka and Qlyasan)*

Physicochemical properties		**Locations**	
		Kani Panka	**Qlyasan**
Particles size distribution (g kg^{-1})	Sand	36	107
	Silt	529	435
	Clay	435	458
	Texture	Silty Clay	Silty Clay
PH		7.70	7.59
Ece (micro Siemens cm^{-1}) or ($\mu S\ cm^{-1}$)		218	490
O.M. (g kg^{-1})		22.4	14.8
$CaCO_3$ (g kg^{-1})		208.3	304.3
Water table (m) from ground level		14	22

Weed identification

Weed plants of both locations were collected and classified into narrow and broad leaved, and identified to their Scientific, English and Kurdish (local) names (*Tables 3* and *4*).

Results and discussion

Effects of seed cleaning, weed control treatments and their interaction on weed dry weight

Weight of weeds that accompany the wheat crop after harvest are a good indicator for the effectiveness of weed control or management process that is applied, and it is reflected directly on the crop yield and quality.

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It is found from *Table 5* that Qlyasan location registered the highest weeds dry weight (160.2 $g.m^{-2}$) which was significantly higher than Kani Panka (120.5 $g.m^{-2}$), this might be due to environmental diversity and water table level, or may be to the initial invading of weeds in Qlyasan because of high rain precipitation during the season 2018-2019 (*Table 1*), specially the rains during spring months in Qlyasan registered 1.5 to 2 times more rain fall comparing to Kani Panka, this gave chance to a group of weed seeds to grow during spring months.

Table 5 illustrates the significant effect of seed cleaning on weed dry weight, figures were 168.8 $g.m\text{-}^{2}$ for non-cleaned seeds versus 112.02 $g.m^{-2}$ for cleaned wheat seeds, in both locations cleaned seeds recorded significant effect on minimizing the weed dry weight, the reduction of weed dry weight reached 34% in both locations, these results are similar to what Norsworthy et al. (2012) reported that using of cleaned seeds is an effective method to control weeds in addition it minimizes introducing new weeds, mechanical cleaned seeds also enhance the establishment of weed-free fields and then keep fields as weed free as possible. Chauhan (2013) also emphasized that cleaning of seeds is one of the strategic methods to minimize effect of weeds. Results of this study are in line with what Hossain (2015) found that seed cleaning resulting in fewer weed seeds being sown with crop seed, also the results were in line with the previous studies by Owen and Powles (2020) which found that crop seed cleaning reduced weed seed contamination.

Table 3. *Scientific names, family, English and Kurdish names of weed plants in Qlyasan location*

Qlyasan narrow leaved weeds			
Scientific name	**Family**	**English name**	**Kurdish name**
Avena fatua L.	Poaceae	Wild oat	*Qalas, paraspelka*
Hordium balbosum	Poaceae	Bulbous barley	*Gezar geya*
Phalaris minor Retz.	Poaceae	Little seed canary grass	*Kapank, bashan, qaram*
Cyperus rotundus L.	Cyperaceae	Nut grass (nut sedge)	*Simel, sotka*
Lolium rigidum	Poaceae	Rigid ryegrass	*Giya ganem*
Lolium temulentum L.	Poaceae	Darnel ryegrass	*Ganema marana*
Sorghum halepense	Poaceae	Johnson grass	*Karoush*
Qlyasan broad leaved weeds			
Carthamus oxyacanthus	Asteraceae	Wild safflower	*Dirkazarda*
Centaurea Pallescens	Asteraceae	Knapweed	*Gawra gla*
Cichorium intybus L.	Asteraceae	Common chicory	*Chaqchaqoka*
Silybium marianum L.	Asteraceae	Milk thistle	*Chaoubaza, Qalughan*
Lactuca virosa L.	Asteraceae	Wild lettuce	*Talishk, Kahowakewi*
Sinapis nigra L.	Brassicaceae	Black mustard	*Khartala, aspand*
Sinapis arvensis L.	Brassicaceae	Wild mustard	*Khartala, garmazhen*
Lupinus albus L.	Fabaceae	Field lupine	*Pulka, wulara*
Galium tricorontum	Rubiaceae	Rough corn bedstraw	*Gertik, noosaka*
Vaccuria pyramidata	Caryophayllaceae	Cow herb	*Glenah*
Melilotus indicus L.	Fabaceae	Sweet clover	*Gochanbakhe*
Vicia calcarata	Fabaceae	Wild vetch	*Paqlamarana (paqloka)*
Convolvulus arvensis L.	Convolvulaceae	Field bindweed	*Laulawa*
Glycyrrhiza galabra	Fabaceae	Liquorice	*Bahlak*
Euphorbia peplus	Euphorbiaceae	Milk weed	*Khursheelk*

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***Table 4.** Scientific names, family, English and Kurdish names of weed plants in Kani Panka location*

Kanipanka narrow leaved weeds			
Scientific name	**Family**	**English name**	**Kurdish name**
Avena fatua L.	Poaceae	Wild oat	*Qalas, paraspelka*
Hordium balbosum	Poaceae	Bulbous barley	*Gezar geya*
Phalaris minor Ritz.	Poaceae	Little seed canary grass	*Kapank, bashan, qaram*
Cyperus rotundus	Cyperaceae	Nut grass (nut sedge)	*Simel, sotka*
Lolium rigidum	Poaceae	Rigid ryegrass	*giya ganem*
Lolium temulentum	Poaceae	Darnel ryegrass	*Ganema marana*
Sorghum halepense	Poaceae	Johnson grass	*Karoush*
Kanipanka broad leaved weeds			
Glycyrrhiza galabra	Fabaceae	Liquorice	*Bahlak*
Galium tricorontum	Rubiaceae	Rough corn bedstraw	*Gertik, noosaka*
Sinapis nigra	Brassicaceae	Black mustard	*Khartala, aspand*
Sinapis arvensis	Brassicaceae	Wild mustard	*Khartala, garmazhen*
Silybium marianum L.	Asteraceae	Milk thistle	*Chaoubaza, Qalughan*
Xanthium strumarium	Asteraceae	Rough cocklebur	*Moosanak, Pizh*
Vicia calcarata	Fabaceae	Wild vetch	*Paqlamarana (paqloka)*
Lactuca virosa L.	Asteraceae	Wild lettuce	*Talishk, Kahowakewi*
Carthamus oxyacanthus	Asteraceae	Wild safflower	*Dirkazarda*
Centaurea Pallescens	Asteraceae	Knapweed	*Gauwragla*
Convolvulus arvensis L.	Convolvulaceae	Field bindweed	*Laulawa*

***Table 5.** Effect of seed cleaning, weed control treatments and their interactions on weeds dry weight (g.m^{-2}) in two locations*

Locations (L)	**Seed cleaning (A)**	**Weed control (W)**					**Location * seed cleaning**
		Control	**Hand weeding**	**Narrow leafed herbicides**	**Broad leafed herbicides**	**Mixture**	
Qlyasan	Cleaned seeds	264.709 b	26.380 ijk	223.312 c	123.097 ef	26.410 IJK	132.781 c
	Not cleaned seeds	373.458 a	59.705 h	262.514 b	174.640 d	68.152 gh	187.694 a
Kani Panka	Cleaned seeds	228.790 c	11.520 k	153.037 de	48.897 hi	14.090 jk	91.2670 d
	Not cleaned seeds	342.335 a	45.325 hij	215.387 c	95.100 fg	51.452 hi	149.920 b
Qlyasan		319.083 a	43.0425 g	242.913 c	148.868 e	47.2812 g	160.237 a
Kani Panka		285.562 b	28.4225 g	184.212 d	71.9987 f	32.7712 g	120.593 b
Cleaned seeds		246.749 b	18.950 g	188.175 c	85.9975 e	20.250 g	112.024 b
Not cleaned seeds		357.896 a	52.515 f	238.950 b	134.870 d	59.8025 f	168.807 a
Weed control mean		302.323 a	35.7325 d	213.562 b	110.433 c	40.0262 d	

LSD 0.05 L = 12.9732, LSD 0.05 A = 10.4237, LSD 0.05 W = 16.4813, LSD 0.05 L * A = 14.7413, LSD 0.05 L * W = 23.3081, LSD 0.05 A * W = 23.3081, LSD 0.05 L * A * W = 32.9626. Different letters represent significant differences between the mean values according to LSD Test ($p \leq 0.05$)

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It is noticed from *Table 5* that cleaned wheat seeds had less weeds grown in both locations and that might not be because only less weed seeds accompanied the crop seeds, but also because cleaning of crop seeds will lead to select large crop seeds to be cultivated, this will raise the vigor of the crop seeds, and overbalance the competition to support the crop among weeds, this is in line with previous studies by Shi et al. (2017) and Kandasamy et al. (2020).

Impact of weed control on weed dry weight

Results in *Table 5* revealed that all weed control treatments were statistically significant in reducing weed dry weight, it is found that hand weeding and herbicides mixture recorded 88% and 86% reduction in weed dry weight respectively comparing to the control results, although both hand weeding and herbicides mixture had significant effect on reducing weed dry weight but there were no significant differences between those two treatments, these results are similar to what found by Hamouda et al. (2021) and Kareem et al. (2018). On the other hand, 63% and 29% reduction in weed dry weight was recorded in the case of broadleaved and narrow leaved herbicides, respectively, also these two treatments had significant differences between them and within all treatments. From the data shown in *Table 5* it is noticed that dry weight of weeds after application of narrow leaved herbicide was 213.56 $g.m^{-2}$ while dry weight of weeds after broadleaved herbicide application was only 110.43 $g.m^{-2}$, this shows that narrow leave weeds are more resistant to herbicides due to narrow selectivity between grassy weeds and wheat crop being both of grass in nature exhibits similar physiology and reaction to herbicides compared to broad-leaved weeds.

There was a significant effect of locations on weed dry weight, *Table 5* explained that Qlyasan record was higher than Kani Panka (160.237 versus 120.593 $g.m^{-2}$ respectively) and this might be due to extra number of weed species that existed in Qlyasan but were not found in Kani Panka (*Tables 3* and *4*).

Seed cleaning and locations interactions

Both *Table 5* and *Figure 2* elucidate significant effects of cleaned wheat seeds in different locations, it is noticed that the best combination for seed cleaning in both locations to minimize weed dry weight was in Kani Panka for cleaned seeds by recording only 91.26 $g.m^{-2}$,while the highest weed dry weight was found in Qlyasan for not cleaned seeds which registered 187.69 $g.m^{-2,}$ In the same trend clean seeds for Qlyasan and not cleaned seeds for Kani Panka registered 132.78 and 149.92 $g.m^{-2}$ respectively. It is obvious from the results that seed cleaning in both locations had significant effect on minimizing weed dry weight, these results were in agreement with those reported by Norsworthy et al. (2012), Qasem (2006), Worku (2010) and Cabardo (2003) meanwhile Qlyasan location recorded higher weed dry weight compared to Kani Panka and that might be due to existing of additional number of weeds in Qlyasan field such as (Common chicory *Cichorium intybus L.*, Field lupine *Lupinus albus L.*, Cow herb *Vaccuria pyramidata*, Sweet clover *Melilotus indicus L.*, Milk weed *Euphorbia peplus*) (*Tables 3* and *4*) which were not found in Kani Panka field. Moreover, rain fall in Qlyasan location was higher than Kani Panka by 13% (1245 mm and 1093 mm, respectively), the extra rainfall concentrated in spring months (march, April, May) when Qlyasan had 56% more rain comparing to Kani Panka.

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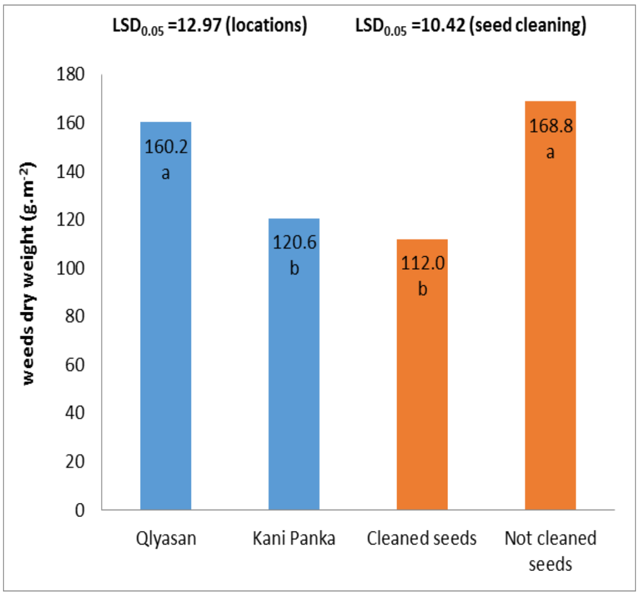

Figure 2. *Effect of locations and seed cleaning on weed dry weight (g.m^{-2})*

Influences of weed control and locations interactions on weed dry weight

As indicated in *Tables 5* and *A1* (in the *Appendix*) the application of herbicides was found to reduce weed dry weight significantly at both locations**.** The maximum and significant reduction in total weed dry weight realized by mixture of both Topic and Granstar herbicides treatment compared with the control treatment at both locations.

Data shown in *Table 5* exhibited the significant effect of weed control treatments on the weed dry weight in both locations, the best result in minimizing weed dry weight was 28.42 g.m^{-2} which obtained in Kani Panka * hand weeding, and this result have no significant differences with Kani Panka * herbicides mixture, Qlyasan * hand weeding and Qlyasan * herbicides mixture, which recorded significant reduction in weed dry weight (32.77, 43.03 and 47.28 g.m^{-2} respectively). Low weed dry weight in the treated pots specially those treated with herbicides mixture may be referred to the suppression of weed growth when herbicides are applied and ultimately reduced weed dry weight over the weedy check plots. From the previous results it is found that herbicide mixtures had reduced weed dry weight in Qlyasan and Kani Panka in a ratio of 85% and 88% respectively, while usage of broadleaved herbicide reduced weed dry weight by 53% in Qlyasan versus 75% in Kani Panka, on the other side the effect of using of narrow leaved herbicides reduced weed dry weight by 23% in Qlyasan versus 35% for the same treatment but in Kani Panka. From the above results it is noticed that weed dry weight reduction because of using herbicide mixtures have convergent results in both locations when compared to the control plots of each location, in addition to superior effect over using narrow leaved and broadleaved herbicides separately, which might be due to synergism effect of both herbicides when used as mixtures together, which means that herbicides treatment exhibited the same trend in reducing weed dry weight at both locations. These results are in line with what was found by Hamouda et al. (2021), Zand et al. (2007), Singh et al. (2008), and Kumar et al. (2018). Effect of the mixture might be due to its high selectivity to both narrow and broad-leaved weeds in the wheat crop.

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Effects of seed cleaning and weed control interactions on weed dry weight

Table 5 explained the significant effect of seed cleaning and weed control on minimizing weed dry weight, the lowest weed dry weight registered significant differences in treatment cleaned seeds with hand weeding and cleaned seeds with herbicides mixture recording (18.95 and 20.25 g.m-^{2}) respectively. On the other hand, the highest value for weed dry weight due to herbicide application was in the treatment of not cleaned seeds * no weed control recording 373.45 g.m^{-2} which shows that non-cleaned seeds and no herbicide usage have the highest infestation of weeds, meanwhile cleaning of wheat seeds with any herbicide treatment show significant differences. It is also seen in the same table that the effect of seed cleaning treatment with no herbicide had same records on weed dry weight (no significant difference) versus non-cleaned seeds with narrow weed herbicide (246.7 and 238.9 g.m^{-2} respectively), which shows that only cleaning of wheat seeds minimizing effect on weed dry weight is equal statistically to the effect of using narrow leaf herbicide (Topic), this result will be a good chance to select seed cleaning instead of using herbicides. From the same table it is illustrated that using of broad leaved herbicides (in both cleaned and non-cleaned seeds) registered less weed dry weight compared to using narrow leaved herbicides and this might be mainly due to the sensitivity of broadleaved weeds to herbicides which also is a result of the big area of broadleaved weeds in addition to the ability of broadleaved weeds in absorption of herbicide droplets solution, and also less cuticle coating leaves of broad weeds, on the other side leaves of narrow weeds are mostly hairy leaves that are coated with wax which minimize the penetration of herbicide solution, primary tissue of the weed leaves is epidermal, mesophyll which is a wax like material retards movement of herbicide solution in and out of leaves, also the angle of leaves for narrow leaved weeds is acute angle which minimize the exposure to herbicide solution while broadleaved weeds are mostly disposed parallel to the soil surface therefore are easier to hit with spray solutions if applied.

Seed cleaning, weed control and locations interactions on weed dry weight

Table 5 showed the significant interactions of all treatments in both Qlyasan and Kani Panka locations on weed dry weight, the lowest weed dry weight was 11.52 g.m^{-2} recorded in the treatment Kani Panka * cleaned seeds * hand weeding and this record did not differ significantly with (Kani Panka * cleaned seeds * herbicides mixture) or (Qlyasan * cleaned seeds * hand weeding) and Qlyasan * cleaned seeds * herbicides mixture), which emphasize that cleaned seeds with herbicides mixtures in both locations lowered weed dry weight significantly, these results of herbicide mixtures are similar with the results of Delchev (2018), Hamouda et al. (2021), Kareem et al. (2018), and Tityanov et al. (2015) when they reported that herbicides mixture of clodinafop-propargyl + tribenuron-methyl had a significant effect on weeds, in addition cleaned seeds also found to be significant on minimizing weed dry weight, and this was supported by results of Hossain (2015), Michael et al. (2010), and Owen and Powles (2020).

Effects of seed cleaning, weed control treatments and their interactions on number of spikes.m^{-2} in two locations

Number of spikes per unit area is considered as one of the important parameters that controls the grain yield in wheat.

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Effects of locations on number of spikes.m^{-2}

Results in *Table 6* illustrated that different locations had different significant effect on the number of spikes/area. Kani Panka location registered 413.47 spikes.m^{-2}, while in Qlyasan it was only 242.30 spikes.m^{-2}, this shows clearly that Kani Panka location was superior in increasing number of spikes per area, and this might be due to the environmental conditions in Kani Panka were better for the growth of wheat crop that season, among those factors humidity or water availability is one of the limiting factors, and as it was recorded the water table of Kani Panka is closer to the surface comparing to Qlyasan, 14 m vs 22 m respectively.

Table 6. *Effect of seed cleaning, weed control treatments and their interaction on number of spikes. m^{-2} in two locations*

Locations (L)	Seed cleaning (A)	Weed control (W)					
		Control	Hand weeding	Narrow leaved herbicides	Broad leaved herbicides	Herbicides mixture	Locations * seed cleaning
Qlyasan	Cleaned seeds	229.25 h	271.75 g	248.50 gh	236.50 gh	271.25 g	251.450 c
	Not cleaned seeds	219.75 h	240.25 gh	234.75 gh	233.25 gh	237.75 gh	233.150 c
Kanipanka	Cleaned seeds	391.25 cde	432.25 bc	375.00 ef	440.50 b	511.25 a	430.050 a
	Not cleaned seeds	346.00 f	420.50 bcd	381.75 def	390.25 de	446.00 b	396.900 b
Qlyasan		224.50 e	256.00 d	241.625 de	234.875 de	254.50 d	242.300 b
Kani Panka		368.625 c	426.375 b	378.375 c	415.375 b	478.625 a	413.475 a
Cleaned seeds		310.250cde	352.000 b	311.750 cde	338.500 bc	391.250 a	340.750 a
Not cleaned seeds		282.875 e	330.375 bcd	308.250 de	311.750 cde	341.875 b	315.025 b
Weed control mean		296.562 d	341.187 b	310.00 cd	325.125 bc	366.562 a	

LSD 0.05 L = 26.0923, LSD 0.05 A = 13.0851, LSD 0.05 W = 20.6893, LSD 0.05 L * A = 18.5051, LSD 0.05 L * W = 29.2592, LSD 0.05 A * W = 29.2592, LSD 0.05 L * A * W = 41.378 Different letters represent significant differences between the mean values according to LSD Test ($p \leq 0.05$)

Effects of seed cleaning on number of spikes.m^{-2}

Table 6 explains the effect of seed cleaning on the number of spikes.m^{-2} in both Qlyasan and Kani Panka locations, through recording 251.45 and 430.05 spikes.m^{-2} respectively. This might be as a result of cleaned seeds which lead to select big size and homogenized seeds for sowing (Tibola et al., 2016) and this was close to what Guillen-Portal et al. (2006) mentioned on wheat plants derived from large seed had a noticeable negative effect on weeds (wild oat) via a reduction in panicles.m^{-2} and seed weight, whereas wheat established from small seed wild oat competition reduced wheat spikes m^{-2}.

In addition, cleaned seeds lead to less weed seeds associated with wheat seeds resulting less weed plants grown and compete the crop plants, the cleaned wheat seeds also meant accurate number of healthy wheat plants per area as mentioned by Lollato (2016) and Elgersma (1990), these wheat plants produce a greater number of spikes (Ries and Everson, 1973; De Lucas Bueno and Froud Williams, 1996).

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Effects of weed control on number of spikes.m^{-2}

Results in *Table 6* illustrates that in Qlyasan area the differences were clearly significant, the highest number of spikes.m^{-2} was recorded in the treatment of hand weeding and using of herbicides mixture, recording 256 and 254.5 spikes.m^{-2} respectively, meanwhile control treatment in Qlyasan was 224.5 spikes.m^{-2}. On the other hand, broad leaved and narrow leaved herbicides individually also recorded significant effect but less than the herbicide mixture, these results are in line with what Al-Chalabi and Al-Agidi (2010) pointed out that using of herbicides to control weeds in wheat fields increased number of spikes.m^{-2}, they referred this result to the absence of weeds that allow the crop to grow with minimum competition on growth factors. Also, in Kani Panka location weed control treatments found to be significant comparing to the control treatment. These results were emphasized by Tawaha et al. (2002) in their study on barley, they indicated that herbicides application resulted in more spikes m^{-2}. Using of narrow leaved herbicides in both locations had significant influence on the number of spikes.m^{-2}, this was also reported by El-Metwally et al. (2015) that the highest value of the wheat spike (358 spikes m^{-2}) was obtained from clodinafop-propargyl spraying (Topic/narrow leaved herbicide).

Effects of seed cleaning and locations interactions on number of spikes.m^{-2}

Data in *Tables* 6 and *A1* for number of wheat spikes.m^{-2} exhibited significant differences among cleaned seeds versus non-cleaned at the locations, the highest records were for the cleaned seeds in Kani Panka, while the lowest were for non-cleaned seeds in Qlyasan recording 430.05 and 251.45 spikes.m^{-2} respectively, high number of spikes may be a result of cleaned seeds which means less weed seeds are competing with wheat seeds when sown, this will be reflected on the vigour of wheat seeds, strong wheat seedling and finally more spikes/area, similar results of clean seeds minimizing effect on weeds was gained by Verma et al. (2015), Cabardo (2003) and Worku (2010).

Effects of weed control and locations interactions on number of spikes.m^{-2}

Results illustrated in *Table 6* showed that weed control in different locations recorded significant influence on the number of spikes/area, the highest record was in the treatment herbicides mixture in Kani Panka and the lowest was in the control (un weeded) of Qlyasan location, 478.62 and 224.50 spikes.m^{-2} respectively. From the data shown in *Table 6* it is clear that herbicides mixture and hand weeding treatments had superiority among other treatments but it is also noted that location effect was significant (*Table A1*), the effect of locations is seen clearly in both control treatments (368.62 spikes.m^{-2} for Kani Panka versus 224.50 spikes.m^{-2} for Qlyasan) and this might be as a result of underground water near to the surface in Kani Panka compared to Qlyasan, which made more moisture to be available for wheat plants, that moisture is in the first order because it is one of the main factors limiting plant growth. It is found from the same table that weed control (either herbicides mixture or even one type of herbicide) showed significant effect on the increasing number of spikes (Tawaha et al., 2002; Turk et al., 2003) but it came in the second order compared to location effect.

Effects of seed cleaning and weed control interactions on number of spikes.m^{-2}

Results obtained from this study showed that seed cleaning with weed control treatments had a notable effect on the number of spikes.m^{-2} (*Table 6*), the highest values

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were in the cleaned seeds with herbicides mixture and cleaned seeds with hand weeding which recorded 391.25 and 352 spikes.m^{-2} respectively, while lower records were found in the uncleaned seeds with no weeding (control) treatment, which registered 282.87 spikes.m^{-2}. In a Comparison between cleaned seeds with herbicides mixture and not cleaned seeds with no weed control, it showed that the effect of using cleaned seeds with herbicides mixture increased the number of spikes.m^{-2} by 28%.

Effects of seed cleaning, weed control and locations interactions on number of spikes.m^{-2}

Wheat spikes number have been calculated under the combination of seed cleaning and weed control treatment of weed management as shown in *Tables 6* and *A1*. Significant difference in number of spikes m^{-2} as a result of seed cleaning and herbicide application compared with control treatments were recorded at both locations. The highest values of wheat spikes number (511.25 spikes.m^{-2}) were obtained from cleaned seeds with herbicides mixture in Kani Panka. Contrarily, the lowest values of the previous trait were obtained from un-weeded check at Qlyasan (219.75 spikes.m^{-2}). Such superior seed cleaning and weeded treatment minimize weed-crop competition and save more available environmental resources for crop plants that improved growth traits which positively reflected on spikes numbers of wheat. The positive effect of weed control practices on yield attributes of wheat crop have been confirmed by several authors. The reason may be mainly due to their effective control of weeds by reducing dry matter of weeds (*Table 5*) with recording a high Weed Control Efficiency % (WCE%) (appendixes *A2*). It is also confirmed by Zoheir Y. Ashrafi (2009) that line sowing treated with herbicides gave the maximum number of spikes m^{-2} (293 spikes.m^{-2}).

In Qlyasan location using of narrow leaved herbicide did not have significant effect compared with using broadleaved herbicides which might be due to the symmetrical effect of each type of weeds alone (Narrow or broadleaved) on the number of wheat spikes.m^{-2}. On the other hand, it is found in Kani Panka location that there are significant differences between the effect of narrow leaved weeds and broadleaved weeds, and this might be because of the proportional effect of different types of weeds between the locations.

Effects of seed cleaning, weed control treatments and their interaction on number of kernels (grains). spike $^{-1}$ in two locations

Number of grains. spkie^{-1} is one of yield components.

Effects of locations on number of kernels (grains) spike^{-1}

There were no significant differences among locations in the number of kernels. spike^{-1}, but Kani Panka location showed higher results 30.052 versus 29.588 kernel. spike^{-1} for Qlyasan location (*Table 7*). Meanwhile Qlyasan location showed significant differences in both cleaned seeds and weed control separately, the cleaned seeds resulted 32.101 and the highest records in weed control was for herbicides mixture was (32.014). The same trend for the weed control treatment effectiveness was observed in Kani Panka location, all treatments recorded significant differences with the control unit (no herbicide application), the highest records were in hand weeding and herbicides mixture (resulting 31.763 and 31.480 grain. spike^{-1} respectively).

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Effects of seed cleaning on number of kernels (grains) spike^{-1}

Results obtained from *Table 7* showed that seed cleaning recorded 31.087 grains.spike^{-1}, which was significantly higher than uncleaned seeds (28.554 grains.spike^{-1}), this might be related to minimizing of weed seeds that are taken out when wheat seeds were cleaned, in addition cleaning of wheat seeds gave a chance to select bigger wheat seeds to be cultivated which finally led to produce healthy plants that may produce better, these results were mentioned by Weimarck (1975) for the effect of cleaned seeds on selecting larges seeds, and the results of De Lucas Bueno and Froud Williams (1996) regarding of the vigour of large seeds, meanwhile Lollato (2016) mentioned that cleaned seeds are more similar in volume, shape and weight which is reflected on the accurate number of plants per area, that all leads to better crop production due to minimizing weeds (Khazaei et al., 2016).

Table 7. *Effect of seed cleaning, weed control treatments and their interactions on number of Kernels (grains). spike^{-1} in two locations*

Locations (L)	Seed cleaning (A)	Weed control (W)					Locations * seed cleaning
		Control	Hand weeding	Narrow leaf herbicides	Broad leaf herbicides	Herbicides mixture	
Qlyasan	Cleaned seeds	28.870 defg	34.400 a	33.417 ab	30.240 cdef	33.577 ab	32.101 a
	Not cleaned seeds	23.355 h	26.015 gh	28.555 efg	27.007 g	30.450 cdef	27.076 c
Kani Panka	Cleaned seeds	31.847 abc	32.272 abc	28.717 defg	27.170 g	30.355 cdef	30.072 b
	Not cleaned seeds	27.112 g	31.252 bcde	27.750 fg	31.437 bcd	32.605 abc	30.031 b
Qlyasan		26.112 e	30.207 abcd	30.986 abc	28.623 d	32.013 a	29.588 a
Kani Panka		29.480 bcd	31.762 a	28.233 d	29.303 cd	31.480 ab	30.052 a
Cleaned seeds		30.358 bcd	33.336 a	31.067 bc	28.705 de	31.966 ab	31.087 a
Not cleaned seeds		25.233 f	28.633 de	28.152 e	29.222 cde	31.527 ab	28.554 b
Weed control mean		27.796 d	30.985 ab	29.610 bc	28.963 cd	31.746 a	

LSD 0.05 L = 1.6225, LSD 0.05 A = 0.9052, LSD 0.05 W = 1.4313, LSD 0.05 L * A = 1.2802, LSD 0.05 L * W = 2.0242, LSD 0.05 A * W = 2.0242, LSD 0.05 L * A * W = 2.8627 Different letters represent significant differences between the mean values according to LSD Test ($p \leq 0.05$)

Effects of weed control on number of kernels (grains) spike^{-1}

Weed control have a significant effect on number of kernels (grains). spike^{-1}, the highest record was for the treatment of herbicides mixture and the lowest number was in the control treatment (no weed control method is applied), that recorded 31.746 and 27.796 grains. spike^{-1} respectively (*Tables 4-8*), also hand weeding showed a significant effect on the number of kernels (grains) of the spike (30.985).

Effects of seed cleaning and locations interactions on number of kernels (grains) spike^{-1}

Table 7 shows the significant differences between treatments on kernels number in spike, the highest record was for the cleaned seeds in Qlyasan location while the lowest was for not cleaned seeds in Qlyasan which registered 32.101 and 27.076 kernels.spike^{-1}

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respectively, while in Kani Panka location no significant differences were observed between cleaned and not cleaned seeds.

Effects of weed control and locations interactions on number of kernels (grains) spike^{-1}

Results obtained from *Table 7* illustrates significant differences between treatments, herbicides mixture in Qlyasan have the high number of kernels.spkie^{-1}, while the lowest result was in the control treatment for Qlyasan location,(32.013 and 26.112 kernels.spike^{-1} respectively), from the same table it is found that there is no significant differences between treatments Kani Panka * hand weeding, Kani Panka * herbicides mixture, Qlyasan * narrowleaf herbicides and Qlyasan * hand weeding (31.762, 31.480, 30.986 and 30.207 respectively), it is understood from these results that herbicides mixture and hand weeding treatments found to be effective on increasing number of kernels.spike^{-1} compared to the control treatment.

Effects of seed cleaning and weed control interactions on number of kernels (grains) spike^{-1}

Interactions of seed cleaning and weed control treatments have significantly influenced the number of wheat kernels.spike^{-1} (*Table A1*), the highest results were registered by cleaned seeds with hand weeding treatment, while the lowest records were in not cleaned seeds with no weed control, that registered 33.336 and 25.233 kernels.spike^{-1} respectively (*Table 7*), however herbicides mixture for both cleaned and not cleaned seeds have significant effect compared to the control, this result is in line with what Khan and Gul (2006) found that weed control affected the number of kernels.spike^{-1}. Using of narrow leaved herbicides with the cleaned seeds significantly and positively affected number of kernels.spike^{-1} (31.067), this agree to what noticed by Ali et al. (2016) that using of narrow leaved herbicides will increase grain production, adding the effect of seed cleaning to narrow herbicide in this treatment has additional positive effect on increasing the grain yield (Edwards and Krenzer Jr, 2006) and forage and total yield production as mentioned by Pinto et al. (2019).

Effects of seed cleaning, weed control and locations interactions on number of kernels (grains). spike $^{-1}$

Results illustrated in *Table 7* shows significant effect of the interaction between seed cleaning, weed control and locations treatments on number of kernels. spike^{-1}, the highest value was in the treatment Qlyasan * cleaned seeds * hand weeding, and the lowest value was Qlyasan * not cleaned seeds * no weed control (34.400 and 23.355 kernels.spike^{-1} respectively). This might be explained by the availability of moisture in Kani Panka due to ground water close to the surface compared to Qlyasan, and also because that cleaned seeds have provided big wheat seeds that had more vigour (Khazaei et al., 2016; Weimarck, 1975; De Lucas Bueno and Froud Williams, 1996), and similar in size which obtained accurate seeding rate (plants/area) (Pinto et al., 2019; Ries and Everson, 1973). In addition, cleaned wheat seeds minimize or even restrict any foreign seeds to accompany sowing wheat seeds that leads to less grown weeds in the plots (Hossain, 2015). On the other hand, using of herbicides mixture (Topic with Granstar) eliminated and controlled more weeds that have been grown from soil buried seeds (seed bank) which reflected on the availability of less weeds and more nutrients, moisture, space and even sun light to wheat crop plants, that led to grow powerful wheat

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plants (Abouziena et al., 2008; Kareem et al., 2018; Al-Wagaa and Mohammed, 2020), all these factors enhanced increasing total spikes weight.

Effects of seed cleaning, weed control treatments and their interaction on 1000 kernel (grain) weight in two locations

Effects of locations on 1000 kernel (grain) weigh

Results shown in *Table 8* indicated that all factors in Qlyasan location have significant effect on 1000 kernel weight, cleaned seeds versus not cleaned seeds have recorded 37.331 and 35.631 g for 1000 kernels weight respectively, also the weed control treatments in Qlyasan have positively affected 1000 kernels weight. The interacting effect of both factors cleaning seeds and weed control was significant comparing to the control treatment, the best combination was in the treatment cleaned seeds * herbicide mixture and cleaned seeds * hand weeding, which both recorded 40.1 g.1000^{-1} kernel weight, that shows as far as weeds existence are minimized through seed cleaning with either hand weeding or herbicides mixture enhanced the increase of 1000 grain weight. In Kani Panka location treatments had significant effect on the 1000 grain weight, results from (*Table 8*) shows that cleaned seeds increased 1000 grain weight of the wheat compared to non-cleaned seeds recording 39.52 and 37.39 g.1000^{-1} respectively, the same trend was found when applying weed control treatments in Kani Panka, hand weeding and herbicides mixture showed superiority compared to the control in increasing 1000 kernel weight, which recorded 40.840 and 40.291 g.1000^{-1} respectively while the control treatment was 35.299 g.1000^{-1} kernel.

Table 8. *Effect of seed cleaning, weed control treatments and their interaction on 1000 grain wheat weight (g) in two locations*

Locations (L)	Seed cleaning (A)	Weed control (W)					Locations * seed cleaning
		Control	Hand weeding	Narrow leafed herbicides	Broad leafed herbicides	Herbicides mixture	
Qlyasan	Cleaned seeds	34.655 ijk	40.120 b	35.672 ghi	36.032 fgh	40.175 b	37.331 b
	Not cleaned seeds	33.470 k	39.155 b	34.882 hij	34.642 ijk	36.005 fgh	35.631 c
Kanipanka	Cleaned seeds	36.320 efg	42.365 a	37.705 cd	39.582 b	41.670 a	39.528 a
	Not cleaned seeds	34.277 jk	39.315 b	37.022 def	37.452 de	38.912 bc	37.396 b
Qlyasan		34.063 f	39.638 b	35.277 e	35.338 e	38.090 cd	36.48 b
Kani Panka		35.298 e	40.840 a	37.364 d	38.518 c	40.291 ab	38.46 a
Cleaned seeds		35.487 f	41.243 a	36.688 de	37.808 c	40.923 a	38.43 a
Not cleaned seeds		33.874 g	39.235 b	35.953 ef	36.048 ef	37.458 cd	36.51 b
Weed control mean		34.68 d	40.24 a	36.32 c	36.93 c	39.19 b	

LSD 0.05 L = 0.6625, LSD 0.05 A = 0.4148, LSD 0.05 W = 0.6558, LSD 0.05 L * A = 0.5867, LSD 0.05 L * W = 0.9276, LSD 0.05 A * W = 0.9276, LSD 0.05 L * A * W = 1.3118 Different letters represent significant difference between the mean values according to LSD Test ($p \leq 0.05$)

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Effects of seed cleaning on 1000 kernel (grain) weight

Cleaned seeds had a significant effect on increasing 1000 kernel weight. Cleaning registered 38.43 versus 36.51 g. for uncleaned seeds (*Table 8*), this result agrees to what Hossain (2015) found that cleaning wheat seeds minimize weeds and to what Al-Chalabi and Al-Agidi (2010) emphasized that minimizing weeds will increase yield and its components.

Effects of weed control on 1000 seeds weight

Results obtained from this experiment revealed the significant effect of weed control treatments on 1000 kernel weight of wheat crop. Data shown in *Table 8* explains that all treatments have the same trend in increasing 1000 kernel weight, hand weeding and herbicides mixture recorded remarkable significant results (40.24 and 39.19 $g.1000^{-1}$ weight respectively), however broadleaved and narrow leaved herbicides treatment showed significant differences compared to the control treatment, 36.93 and 36.32 versus 34.68 $g.1000^{-1}$ weight respectively. This result was in agreement with the findings of Riaz et al. (2006) who reported that maximum 1000-kernel weight of wheat was produced with weed control by herbicides + hand weeding. Also, Hamouda et al. (2021) emphasized that using herbicides to control weeds in wheat fields increased 1000 kernel weight.

Effects of seed cleaning and locations interactions on 1000 kernel (grain) weight

The examination of the data presented in *Table 8* showed the effect of seed cleaning treatments and locations on 1000 kernel weight of the wheat crop, the highest results was in cleaned seeds in Kani Panka and the lowest was in not cleaned seeds in Qlyasan location, 39.528 and 35.631 g 1000^{-1}. kernel weight respectively. However, cleaned seeds in both locations registered higher results compared to uncleaned seeds, while Kani Panka showing superiority over Qlyasan might be due to environmental differences or different soil properties (*Tables 1* and *2*).

Effects of weed control and locations interactions on 1000 kernel (grain) weight

With respect to the wheat thousand kernel weight, the data presented in *Table 8* showed a significant effect of the weed control treatments and locations interactions, the highest record was in Kani Panka * hand weeding and the lowest found in Qlyasan * no weed control (40.840 and 34.063 $g.1000^{-1}$ kernel weight respectively). In Qlyasan location both narrow leaved and broadleaved herbicides have statistically the same result, while in Kani Panka there were significant differences between treatments of broad leafed and narrow leafed herbicides which recorded 38.518 and 37.364 respectively, they also have significant differences compared to the control treatment. This might be referred to soil moisture content due to close water table in Kani Panka compared to Qlyasan, also the diversity of weeds between both locations; as Qlyasan location found to have more broad leave weeds (*Tables 3* and *4*).

Effects of seed cleaning and weed control interactions on 1000 kernel (grain) weight

Cleaned seeds with hand weeding or herbicides mixture treatments recorded significant results (41.243 and 40.923 g 1000^{-1} kernel weight respectively) compared to the control (not cleaned seeds with no method of weed control 33.874 g) as

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explained in *Table 8*, these results explain how much seed cleaning with hand weeding or herbicides mixture was effective to increase 1000 kernel weight. These results reflect controlling and minimizing weeds in these treatments (*Tables 5* and appendix A-1).

Effects of seed cleaning, weed control and locations interactions on 1000 kernel (grain) weight

Results displayed in *Table 8* explained that interaction effect of seed cleaning, weed control and locations was significant on 1000 kernel weight, the highest value was in the treatment Kani Panka * cleaned seeds * hand weeding while the lowest record was for the treatment Qlyasan * not cleaned seeds * no weed control (42.365 and 33.470 $g.1000^{-1}$ kernel weight respectively). Meanwhile in Kani Panka the treatments cleaned seeds * hand weeding and cleaned seeds * herbicides mixture did not register any statistical differences, the same was observed in Qlyasan for the treatments cleaned seeds * hand weeding and cleaned seeds * herbicides mixture (40.120 versus 40.175 $g.1000^{-1}$ kernel weight respectively), these results show that the effect of hand weeding is equal to herbicides mixture.

Effects of seed cleaning, weed control treatments and their interaction on wheat yield (grain yield) in two locations

Grain yield is the aim of any production process and the most important parameter of any weed control program.

Effects of locations on wheat yield

Results collected from this study illustrates that research factors have significant effect on wheat grain yield, *Table 9* shows significant effect of the location on grain yield, it is found that Kani Panka was superior compared to Qlyasan (487.10 and 274.55 $g.m^{-2}$ respectively), which means 43.6% production difference between both locations, this might be referred mainly to the water availability in Kani Panka (ground water is found at the depth of 14 m in Kani Panka versus 22 m for Qlyasan) or soil property (*Table 2*), in addition this difference in the production might be the result of the weed diversity between both locations, Qlyasan was invaded by more weed species (*Tables 3* and *4*).

Effects of seed cleaning on wheat yield

A perusal of data indicate that seed cleaning had a significant effect on wheat yield. Results in *Table 9* showed that cleaned seeds recorded 405.06 $g.m^{-2}$ while wheat grain yield for uncleaned seeds was 356.60 $g.m^{-2}$, these results are combined with the minimizing of weed dry weight as explained in *Figure 2*. Cleaned seeds led to increase in grain yield, this result was emphasized by Edwards and Krenzer Jr (2006) who mentioned that cleaned seeds will increase grain yield.

Effects of weed control on wheat yield

Results in *Tables 9* and *A1* illustrate significant impact of weed control treatments on wheat grain yield, a close scanning of the data showed that among different herbicidal treatments, the highest significant value of wheat grain weight was obtained from

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herbicides mixture treatment (467.86 gm^{-2}) while the lowest value was (293.568 gm^{-2}) the result of unweeded (control) plots**.** The enhancement of wheat growth in the weeded plots might be attributed to the efficiency of herbicides in weed elimination (*Table 5*), and consequently reduced weed competitive ability against wheat crop, these results are in a good correlation with those of Al-Wagaa and Mohammed (2020) and El-Metwally et al. (2010) who reported that herbicides application to cereal crops during early stages of development have greatly decreased weed population over weedy check which ultimately increased grain yield by reducing competition among weeds and crop plants for light, nutrients, moisture and other growth requirements.

Table 9. *Effect of seed cleaning, weed control treatments and their interaction on wheat yield (g.m^{-2}) in two locations*

Locations (L)	Seed cleaning (A)	Weed control (W)					Locations * seed cleaning
		Control	Hand weeding	Narrow leafed herbicides	Broad leafed herbicides	Herbicides mixture	
Qlyasan	Cleaned seeds	231.53j	334.46g	299.00h	245.05ij	366.04f	295.219 c
	Not cleaned seeds	199.83k	249.93ij	267.21i	226.46jk	325.97gh	253.887 d
Kani Panka	Cleaned seeds	397.35e	573.74b	484.00d	483.14d	636.20a	514.891 a
	Not cleaned seeds	345.54fg	535.21c	408.11e	464.41d	543.21c	459.300 b
Qlyasan		215.68 i	292.20 g	283.11 g	235.76 h	346.01 f	274.55 b
Kani Panka		371.45 e	554.48 b	446.06 d	473.78 c	589.71 a	487.10 a
Cleaned seeds		314.443 f	454.10 b	391.50 c	364.10 d	501.12 a	405.06 a
Not cleaned seeds		272.693 g	392.57 c	337.665 e	345.44 de	434.59 b	356.60 b
Weed control mean		293.56 d	423.33 b	364.58 c	354.77 c	467.86 a	

LSD 0.05 L = 13.4528, LSD 0.05 a = 8.8165, LSD 0.05 w = 13.940, LSD 0.05 L * a = 12.468, LSD 0.05 L * w = 19.7144, LSD 0.05 a * w = 19.7144, LSD 0.05 L * a * w = 27.8804 Different letters represent significant differences between the mean values according to LSD Test ($p \leq 0.05$)

Effects of seed cleaning and locations interactions on wheat yield

Cleaned wheat seeds produce a high vigour seed that create more strong seedlings and assist to establish growing of healthy crop plants, which will produce more grain yield. Results obtained from this study showed that significant superiority in grain yield was in the treatment cleaned seeds * Kani Panka, while the lowest grain yield was found in not cleaned seeds * Qlyasan (514.891 and 253.887 g m^{-2} respectively), results shown in *Table 9* ensures what Keeble and Hale (1982), Shi et al. (2017) found, who mentioned that cleaned seeds will produce more healthy plants that gives higher grain yield (Edwards and Krenzer Jr, 2006; Lollato, 2016; Worku, 2010), cleaned wheat seeds minimized or eliminated weed seeds which is reflected on minimizing weed plants that germinate and grow in those plots leading to less competition with wheat crop plants, same trend is noticed in *Table 5*, the lowest weed

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dry weight (91.267 g.m^{-2}) led to register the highest wheat grain yield (514.891 g.m^{-2}) for the treatment Kani Panka * cleaned seeds (*Table 9*).

Effects of weed control and locations interactions on wheat yield

Results from *Table 9* obviously shows the significant effect of different weed control treatments on wheat grain yield, the highest grain yield registered in the treatment of herbicides mixture in Kani Panka location (589.71 gm^{-2}), while the lowest records were in the treatment control (no-weeding) in Qlyasan (215.68 g.m^{-2}), simultaneously weed control had notable effects on the grain yield in Qlyasan. Herbicides mixture and hand weeding had higher grain yield compared to the control treatment (346.01, 292.19 and 215.68 g.m^{-2} respectively) the use of herbicides mixture minimized weed dry weight significantly (*Table 5*) through minimizing both narrow and broadleaved weeds, the highest record was found in herbicides mixture in Kani Panka treatment while the lowest spikes weight was also registered in the control (no-weeding) in Qlyasan treatment.

While all weed control treatments in Kani Panka registered significant effects on wheat grain yield compared to the control, among weed control treatments and due to using of herbicides the highest record was in the herbicides mixture treatment and the lowest was in the narrow leaved (Topic) herbicide treatment 589.710 and 446.056 g.m^{-2} respectively (*Table 9*).

Effects of seed cleaning and weed control interactions on wheat yield

Data exhibited in *Table 9* showed a significant effect of the interactions between both factors, the highest records were in the cleaned seeds with herbicides mixture, while the lowest record was in the control treatment (uncleaned seeds with no weed control) which registered 501.126 and 272.693 g.m^{-2} respectively, it is found from the same results that cleaned wheat seeds with hand weeding treatment have the same effect (no significant difference) of uncleaned seeds with herbicides mixture (454.10 and 434.59 g.m^{-2} respectively), on the other hand cleaned seeds with hand weeding have similar effect (no significant difference) with cleaned seeds but with the use of only narrow leaved herbicide (392.57 and 391.5 g.m^{-2} respectively).

Effects of seed cleaning, weed control and locations interactions on wheat yield

Results collected from this study clearly shows the significant effect of seed cleaning, weed control and locations interactions on wheat yield, it is found from *Table 9* that Kani Panka * cleaned seeds * herbicides mixture treatment have the highest grain yield while the treatment Qlyasan * not cleaned seeds * no weed control gained the lowest records (636.20 and 199.83 g.m^{-2} respectively). The high records may be referred to different reasons, first of all it is clearly noticed that different locations have significant effect on wheat grain yield, the underlining reason might be linked to weed flora in wheat and their competitive abilities differ with changes in the environment and the availability of soil moisture. Water table closeness to soil surface in Kani Panka location prepared better conditions for growing wheat crops compared to Qlyasan location, in addition weed flora diversity (*Tables 2, 3* and *4*) which illustrated that more weed types were found in Qlyasan location that leads to more stress on wheat plants in Qlyasan, and as a result the wheat grain yield in Kani Panka was higher than Qlyasan. Furthermore, cleaned wheat seeds are more vigour and

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powerful to compete weed plans and this result was assured by De Lucas Bueno and Froud Williams (1996), Khazaei et al. (2016) and Al-Wagaa and Mohammed (2020). Less weed existence was observed when seeds were cleaned before sowing, this result was also emphasized by Hossain (2015), Verma et al. (2015), and Worku (2010) who mentioned that cleaning of crop seeds before sowing minimize weeds in the field. However, the cleaned seeds effect to increase grain yield through minimizing weeds was mentioned by several researchers (Chicouene, 2020; Butovchenko et al., 2018; Norsworthy et al., 2012).

The interaction combination of the treatment Kani Panka * cleaned seeds * herbicides mixture which had the higher grain yield (636.20 $g.m^{-2}$) may be referred to the effect of the use of herbicides mixture which minimized and controlled weed plants that have been grown with the wheat crop after sowing. Those weed seeds and propagules were a part of the soil seedbank, consist of narrow and broadleaved weeds, are controlled by Topic and Granstar herbicides mixture. Controlling of weeds that came from the soil by herbicides gave additional chances for wheat crop to use growth factors efficiently, which resulted to establish strong, tall plants, and productive wheat plants that produced remarkable grain yield. The positive effect of herbicides mixture to increase grain yield was supported by Al-Wagaa and Mohammed (2020).

On the other side the lowest yield was in the treatment of un-cleaned seeds with no weeding (199.93 $g.m^{-2}$), this treatment registered the highest weed dry weight (373.45 $g.m^{-2}$) as shown in *Table 5* and this reflects the general combined relation; high weed dry weight influences negatively and significantly the grain yield, this insures that high grain yield is associated with minimizing of weeds through seed cleaning or weed control after sowing.

Also from *Table 9* it is found that using cleaned seeds with narrow leaved herbicides in Qlyasan had significant difference compared to the treatment of cleaned seeds and broadleaved herbicides (299 and 245.05 $g.m^{-2}$ respectively), which showed the increase of yield by 23% and 14% respectively compared to control treatment, and this reflects the significant controlling effect of narrow leaved weeds, this result agrees to what Khan and Haq (2002) found in their study on wheat crop yield losses due to weeds when they mentioned that narrow leaved weeds are in charge of 30% of the wheat yield loss versus 24% losses caused by broadleaved weeds.

The same trend was found in the interactions of two factors in Kani Panka location, the highest record was in cleaned seeds with herbicides mixture while the lowest record was in the uncleaned seeds with no herbicide application (636.20 and 345.54 $g.m^{-2}$ respectively), this ensures that cleaned wheat seeds which contained no weed seeds show greater vigour due to bigger seeds selected and similarity in shape and size because of cleaning process can produce more healthy plants (Shi et al., 2017; Tibola et al., 2016; Ries and Everson, 1973) and as a result will produce more grain yield (Edwards and Krenzer Jr, 2006), in addition using of herbicides mixture enhance the weed control for those weed seeds that exist in the soil and grow with the crop plans and finally lead to higher grain yield, many papers have supported this approach (Kareem et al., 2018; Salim et al., 2017; Ali et al., 2016; Tityanov et al., 2015)

Conclusion

The results of this study indicated that herbicides mixture found to be effective in minimizing weed dry weight and in increasing of wheat yield, also the results assured

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that seed cleaning before sowing will enhance wheat yield and minimize weed dry weight, therefore in order to minimize using herbicides which cause environmental pollution it is recommended to apply seed cleaning process for wheat before sowing.

Recommendations

Seed cleaning process is effective in minimizing weeds; therefore, it is recommended to implement new studies on the comparison between, the cost and the environmental impact of using of herbicides as traditional method, compared to only using of seed cleaning.

As there are several seed cleaning factories and different mobile machines in Kurdistan region/Iraq, it is suggested to study and evaluate those machines in order to find out which type is most feasible and suitable to local conditions (weeds, crops, land and environment factors).

Seed cleaning machines work in different adjustments such as speeds and variable air discharge in addition to various sieve holes and shapes, additional research studies are needed to find which type of weeds are most vulnerable to seed cleaning method and adjustments, and the evaluation of the impact of captured weed seeds due to cleaning by machines on the crop production.

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APPENDIX

Table A1. *ANOVA table for the land experiment*

Source	DF	Means square (MS)					
		Weeds dry weight (g/m^2)	Number of spikes/m^2	Spikes weight (g/m^2)	Number of grains/spike	1000 grain weight	Grain yield (g/m^2)
Locations	1	31433.6**	5582 81**	1485562**	4.29201 ^{NS}	78.507**	3882588**
Replicates [location] and random	6	562.201 ^{NS}	2497.1**	2993.71*	8.79384 ^{NS}	1.46627 ^{NS}	735.72 ^{NS}
Seed cleaning	1	64485.2**	427.813 ^{NS}	34493.2**	128.296**	73.4403**	70589**
Locations * seed cleaning	1	69.9698 ^{NS}	10328.5**	4934.86*	124.176**	0.93528 ^{NS}	6535.94*

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Weed control	4	214000**	11379.7**	101707**	39.7716**	80.09**	103949**
Locations * weed control	4	3044.34**	3935.18**	14333.3**	21.0086**	2.6579 *	20035.9**
Seed cleaning * weed control	4	3890.09**	1902.5*	2929.16*	25.2626**	3.9114**	2987.07 NS
Locations * seed cleaning * weed control	4	134.203 NS	2584.33**	3486.9 *	7.75345 NS	1.67539 NS	5101.79**
Error	54	540.6	634.4	821.6	4.0777	0.8562	1205

Table A2. *Effect of seed cleaning, weed control treatments and their interactions on weed control efficiency % (WCE%) in two locations*

Locations (L)	**Seed cleaning (A)**	**Weed control (W)**					
		Control	**Hand weeding**	**Narrow leafed herbicides**	**Broad leafed herbicides**	**Herbicides mixture**	**Locations * seed cleaning**
Qlyasan	Cleaned seeds	--------	90%	15.6%	53.49%	90%	29.25%
	Not cleaned seeds	--------	84%	29.7%	53.23%	81.75%	---------
Kanipanka	Cleaned seeds	--------	94.96%	33.11%	78.62%	93.84%	39.12%
	Not cleaned seeds	---------	86.76%	37.08%	72.22%	84.97%	---------
Qlyasan		--------	86.51%	23.87%	53.33%	85.18%	---------
Kani Panka		-------	90.04%	35.49%	74.47%	88.52%	
Cleaned seeds		---------	92.32%	23.73%	65.14%	91.19%	---------
Not cleaned seeds		---------	85.32%	33.23%	62.31%	83.29%	
Weed control mean		---------	88.18%	29.35%	63.47%	86.76%	---------

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