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Effects of pre-harvest application of parquat on grain moisture reduction, grain yield and quality of rapeseed (*Brassica napus* L.) cultivars

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ABSTRACT
Pre-harvest desiccation of rapeseed crop may allow a more timely harvest as well as increase the speed and harvest operation efficiency as a second crop after rice. An effective desiccant which could be used as a harvest-aid with no negative effects on rapeseed yield and quality would be advantageous for oil seed crop producers and may reduce yield losses with no interferential effects on rice cultivation. Field experiment s were carried out in a split plot design at Rice Research Institute of Iran (RRII) in the 2004-2005 cropping season. Paraquat was applied to Hyola308, Hyola401, Hyola420 and RGS003 rapeseed cultivars as main plots at the rates of 0.2, 0.4, 0.8 lit. based on 20% ai.ha^{-1} and a non-treated plot (sub-plot) was used as a control. Paraquat treatments were applied based on grain moisture content of 40% to one third of bottom siliques of inflorescence on the main stem in late April to late May. Results showed that the effect of paraquat application was significant on grain moisture reduction rate, grain yield and oil content. Paraquat at 0.8 lit.ha^{-1} promoted daily grain moisture reduction (2.94% day^{-1}) compared to the control (1.75% day^{-1}) and harvest time (5-7 days earlier than control) with no adverse effects on grain yield and oil content. Grain yield of treated plants were the same or higher than the control. The highest grain yield was obtained with 0.4 lit.ha^{-1} paraquat (2370 kg.ha^{-1} in Hyola420 vs. the control; 2159 kg.ha^{-1}). Results also showed that paraquat application had no adverse effect on oil content and fatty acids profile. Oileic acid content in Hyola308 at 0.2, 0.4 and 0.8 lit.ha^{-1} of paraquat and the control were 64.93, 64.22, 64.25 and 65%, respectively. Mean residues of paraquat in the grains for the medium to low application rates were 5.62 and 2.61 mg.kg^{-1}, respectively and all of its rates were lower than the toxicity threshold. It can be concluded that paraquat in reduced doses, can be used as a proper desiccant in rapeseed cultivation.

Keywords: *Chemical desiccation, Grain yield, Harvest, Oil content, Paraquat and Rapeseed.*

INTRODUCTION

Rapeseed (*Brassica napus* L.) production in the southern coastal areas of the Caspian Sea (Guilan and Mazandaran provinces, Iran) has been of interest as a second crop after rice harvest in recent years (www.guilanagri-jahad.ir and www.maj.ir/statistics/ cultivation database). It is usually sown in October to November and harvested from mid April to late May by swathing method. In this method, based on climatic condition, the harvested plants remain on stubbles for one to two days to dry and they are threshed thereafter (Sims, 1983). Hence, late harvest of rapeseed may interfere with transplanting operations, reduce growth duration and increase yield losses of rice crop. In addition, the non uniform flowering and ripening nature of the indeterminate rapeseed commercial varieties usually leads to siliques shattering and yield losses prior to harvest.

Pre-harvest desiccation of grain crops may provide more timely harvest as well as increase the speed and harvest operation efficiency. An effective desiccant which could be used as a harvest-aid with no negative effects on grain yield and quality would be advantageous for grain crop producers and may reduce yield losses. The efficacy of desiccants has been widely reported for leguminous crops (Pea; Cole and Cerdeira, 1982; Soybean; Ellis, *et al*., 1998; Bennett and Shaw, 2000). Glyphosate

[(N-(phosphonylmethyl) glysine], paraquat (l,l'-dimethyl-4,4' bipyridylium ion) and sodium chlorate ($NaClO_3$) have been applied as desiccants in canola, soybean and rice (Cerkauskas, *et al*., 1982; Ratnayake, Shaw, 1992; Ellis, *et al*., 1998; Cessna, *et al.,* 2000; Darwent, *et al.,* 2000; Eastin, 1978; Eastin, 1980; Flengmark, 1983; Sims, 1983 and Bond and Bollich, 2007). Eastin (1978) reported that 10 days pre-harvest application of paraquat at doses up to 0.56 $kg.ha^{-1}$, had no negative effects on rough rice or head rice yield. No adverse effects of diquat, ghlyphosate, paraquat or sodium chlorate application on seed germination and 1000 grain weight of rice were reported subsequently (Eastin, 1980).

Bipyridylium viologen dyes- diquat and paraquat- act by intercepting electrons on the reducing side of photosystem I. The viologen dyes are autooxidizable, immediately reducing oxygen to superoxide. Thus viologen dyes not only interfere with photosynthetic electron transport, but the superoxide they produce, causes additional damage by rapid inactivating chlorophyll and oxidizing chloroplast membrane lipids and enhance drying down of grain and foliage of the crop, including indeterminate crop growth and late tillering, which may interfere with harvest operations (Vaughan, 2003; Ecobichon, 2001 and Lock and Wilks, 2001).

Although there is a potential for pre-harvest treatment of rapeseed with paraquat, similar residues of paraquat in rapeseed grain data were lacking. Since paraquat is usually readily absorbed by living shoots, there is a potential for the translocation of paraquat into the developing grains of treated plants (Vaughan, 2003; Ross and Lembi, 1992 and Lock and Wilks, 2001).

The objective of the present study was to examine the effects of several rates of paraquat application as a pre-harvest desiccant, on grain moisture reduction, grain yield and quality in four rapeseed cultivars.

MATERIALS and METHODS

The effects of paraquat as a pre-harvest desiccant on grain moisture reduction rate, harvest time, grain yield and quality of rapeseed (*Brassica napus* L.) cultivars were studied in a split plot layout field experiment based on randomized complete block design with three replications at the Rice Research Institute of Iran (RRII), Guilan, Iran, (37°,16´ N, 51°,3´ E and 7 m elevation from sea level) in the 2004-2005 cropping season in silty- clay soil (pH=7.2; $EC(dS.m^{-1})=1.37$; OC(%)=2.08; N(%)=0.155; $P(mg.kg^{-1})=29$; $K(mg.kg^{-1})=192$). Paraquat was applied to four spring rapeseed cultivars (Hyola308, Hyola401, Hyola420 and RGS003) (all double low, early to moderate maturity with 40-45% oil content in grains), as main plots at the rates of 0.2, 0.4, 0.8 lit. based on 20% $ai.ha^{-1}$ and a non-treated plot (sub plot) was used as a control. Seeds were drill-seeded in late October by hand at a seeding rate of 80 plants m^{-2} in 15 m^2 plots. Cropping operations were accomplished based on recommended methods. Paraquat treatments were applied to plants based on grain moisture content of 40% to one third of bottom siliques of inflorescence on the main stem between late April to late May with a backpack sprayer equipped with regular flat-fan spray nozzles at a pressure of 0.2 bar. The siliques on the bottom one third of inflorescence on main stem were harvested and the grains were extracted and examined for grain moisture content, 24 hours after treatment. Samplings were continued on a daily basis to determine the rate of moisture reduction of grains. Samples were obtained from all sprayed plots plus corresponding control plots. Sampling discontinued after the moisture content of the grains declined to less than 15%. Plants were harvested by swathing approximately 15 cm above the soil surface thereafter. Harvested plants were put on stubbles in the field to air-dry at ambient temperature and then were threshed with a stationary plot head thresher with 12% moisture content. 1000 grain weight was measured on 30 random selected plants in each plot. Grain yield was measured in 6 m^2 of each plot based on 12% grain moisture content. Oil content of the grains was determined with solution extraction method (Soxtec System HT, Tecator, Sweden). Sample extracts were analyzed using HPLC (Varian CP, 3800, Netherlands, Capillary Column: C18, temperature: 175°C, Injector and Detector temperature: 250°C, Carrying gas: Nitrogen, Flow rate: 1 $ml.sec^{-1}$) for fatty acids profile determination. Milled grain samples were extracted using aqueous HCl solution (2 M) followed by filter and silica absorbent cleanup. Sample extracts were analyzed using HPLC (HP 1100, USA, Capillary Column: C18, Flow rate: 2.2 $ml.min.^{-1}$) and residues of paraquat in grains were detected. All statistical analysis were performed using SAS software (ver. 9.0) and mean comparisons were based on LSD test. Data on grain oil content were transformed to ArcSin $\sqrt{X}$ prior to analysis.

RESULTS and DISCUSSION

The weather following paraquat application was warm and sunny to partly cloudy with no rainfall (Table 1). Analysis of variance showed a significant effect of paraquat on grain moisture content of rapeseed cultivars (Table 2).

Mean comparison showed a considerable reduction in rate of grain moisture content compared to that of controls in all samplings (Table 3). Mean comparison of average moisture reduction showed a significant reduction rate in rapeseed cultivars. The lowest and highest moisture reduction rates (2.49 and $2.83\%.day^{-1}$) were observed in Hyola308 and Hyola401, respectively (Table 4). Grain moisture reduction rate showed a slow drydown trend in the first 7 days after treatment and was promoted 4 days thereafter, parallel with the increase in ambient temperature (Table 1) (1.75, 2.78, 2.88 and $2.94\%.day^{-1}$ in 0, 0.2, 0.4 and 0.8 $lit.ha^{-1}$ of paraquat, respectively).

Table 1. A synopsis of weather condition of experimental site following paraquat application up to final sampling

Days after treatment	Temperature (c°) Max.	Min.	Avg.	Rainfall (mm)	Relative Humidity(%)	Sunny hours
1	24.2	11.0	17.6	0	80	9.8
2	24.2	13.5	18.9	0	80	9.8
3	26.0	13.5	19.8	0	69	12.4
4	27.8	12.0	19.9	0	70	12.4
5	27.6	12.8	20.2	0	69	12.3
6	28.6	14.4	21.5	0	73	12
7	29.8	16.8	23.3	0	78	10
8	31.8	18.6	25.2	0	74	9.2
9	33.4	20.2	26.8	0	74	11.4
10	32.8	20.0	26.4	0	84	11
11	32.8	21.0	26.9	0	78	8.1
12	31.6	21.4	26.5	0	75	6

Weather information taken from the Guilan Meteorology Office (www.gilmet.ir).

Table 2. Analysis of variance for grain moisture content of four rapeseed cultivars under four levels of paraquat application (1 to 12 are indicative of days after paraquat application)

		Mean of Squares (MS)											
S.O.V	d.f	1	2	3	4	5	6	7	8	9	10	11	12
Replication	2	3.05	4.23	3.46	3.96	3.38	4.58	2.79	2.36	2.67	1.67	2.45	2.65
Rapeseed cultivars	3	1.61*	2.17**	0.37ns	22.07**	67.03**	90.09**	64.94**	74.04**	52.06**	43.86**	35.21**	58.07**
E_a	6	0.02	0.02	0.11	0.05	0.07	0.054	0.005	0.07	0.02	0.10	0.06	0.06
Paraquat rates	3	22.67*	78.25**	291.91**	311.92**	376.51**	390.57**	349.31**	277.7**	387.67**	381.54**	325.27**	264.54**
Cultivar×Paraquat	9	0.4ns	0.075*	0.11 ns	0.0017ns	0.04 ns	0.19ns	0.054 ns	1.99**	5.19**	6.46**	11.11**	13.67**
E_b	24	0.27	0.03	0.11	0.03	0.07	0.12	0.06	0.04	0.06	0.17	0.03	0.04
C.V (%)		1.17	0.46	0.98	0.62	0.99	1.57	0.51	0.97	1.24	2.43	1.17	1.63

*, **: Significantly different at *P*=0.05 and *P*=0.01 probability levels, respectively; ns: Non significant

Table 3. Mean comparison of grain moisture content (%) of four rapeseed cultivars under four levels of paraquat application (1 to 12 are indicative of days after paraquat application)

	Days after application											
Paraquat rates (lit.ha^{-1})	1	2	3	4	5	6	7	8	9	10	11	12
0.2	43.10^{b}	38.80^{b}	34.66^{b}	31.26^{b}	29.19^{b}	28.09^{b}	25.82^{b}	22.94^{b}	19.25^{b}	15.84^{b}	14.28^{b}	11.74^{b}
0.4	42.26^{c}	35.97^{c}	34.49^{b}	30.58^{c}	27.90^{c}	27.49^{c}	22.33^{c}	21.66^{c}	19.05^{b}	15.55^{b}	11.67^{c}	9.71^{c}
0.8	40.55^{d}	34.69^{d}	26.20^{c}	22.98^{c}	19.98^{d}	18.30^{d}	17.56^{d}	16.79^{d}	13.81^{c}	11.92^{c}	9.94^{d}	8.39^{d}
Control	43.65^{a}	40.26^{a}	37.69^{a}	35.18^{a}	33.38^{a}	31.69^{a}	30.31^{a}	28.50^{a}	27.56^{a}	25.13^{a}	21.71^{a}	18.93^{a}

Means with similar letters in each column are not significantly different according to LSD Tes

Table 4. Mean comparison of grain moisture content (%) of four rapeseed cultivars under four levels of paraquat application (1 to 12 are indicative of days after paraquat application)

	Days after application											
Rapeseed cultivars	1	2	3	4	5	6	7	8	9	10	11	12
Hyola308	42.90^{a}	38.04^{a}	33.08^{a}	32.03^{a}	31.15^{a}	30.58^{a}	27.50^{a}	26.19^{a}	23.03^{a}	19.96^{a}	16.97^{a}	15.49^{a}
Hyola401	42.08^{c}	37.09^{c}	33.18^{ab}	29.18^{c}	26.30^{c}	24.79^{c}	22.70^{d}	21.09^{c}	18.76^{c}	16.00^{c}	13.43^{c}	10.98^{c}
Hyola420	42.18^{c}	37.19^{c}	33.28^{ab}	29.28^{bc}	26.40^{bc}	25.07^{b}	22.81^{c}	21.19^{bc}	18.81^{c}	16.07^{c}	13.50^{c}	11.03^{bc}
RGS003	42.40^{b}	37.41^{b}	33.49^{a}	29.51^{b}	26.63^{b}	25.24^{b}	23.03^{b}	21.41^{b}	19.06^{b}	16.41^{b}	13.75^{b}	11.27^{b}

Means with similar letters in each column are not significantly different according to LSD Test

The interaction between rapeseed cultivars and paraquat application rates were significant on days 7 to 12 (Table 2). Hyola401 plants treated with 0.8 lit.ha^{-1} paraquat, showed the highest grain moisture reduction rate, reaching the optimum moisture level for harvest on the 8th day after treatment (Table 5). All paraquat rates promoted harvest time (5-7 days earlier than control) (Table 6).

Table 5. Interaction effects of rapeseed cultivars and paraquat rates on grain moisture content (%) at days 8 to 12th after application (DAA)

	Rapeseed cultivars															
	Hyola308				Hyola401				Hyola420				RGS003			
DAA	Rates of paraquat (lit.ha^{-1})				Rates of paraquat (lit.ha^{-1})				Rates of paraquat (lit.ha^{-1})				Rates of paraquat (lit.ha^{-1})			
	Control	0.2	0.4	0.8	Control	0.2	0.4	0.8	Control	0.2	0.4	0.8	Control	0.2	0.4	0.8
8	34.00 a	25.68 e	25.10 ef	19.99 klmj	26.53 bcd	21.89 ghi	20.38 jkl	15.57 op	26.65 bc	21.99 gh	20.48 jk	15.70 no	26.85 b	22.20 g	20.68 j	15.91 n
9	33.63 a	21.33 e	21.06 f	16.13 m	25.48 bcd	18.44 ghij	18.24 ghijkl	12.90 nop	25.55 bc	18.54 ghi	18.35 ghijk	13.00 no	25.76 b	18.72 g	18.56 gh	13.21 n
10	31.18 a	17.95 e	17.72 ef	13.07 lm	22.03 dc	15.00 ghij	14.47 ghjkl	11.50 nop	23.14 bc	15.11 ghi	14.58 ghijk	11.61 n	23.35 b	15.32 gh	15.54 g	11.55 no
11	28.1 a	16.76 e	13.88 f	9.21 p	19.57 bcd	13.32 ghi	10.37 lm	10.10 mno	19.68 bc	13.43 fgh	10.91 jk	10.16 mn	19.88 b	13.63 fg	11.12 j	10.80 jkl
12	26.34 a	14.94 e	12.70 f	7.69 mnop	16.37 bcd	10.57 ghi	8.60 jklm	8.40 jklmno	16.49 bc	10.64 gh	8.68 jkl	8.51 jklmn	16.69 b	10.82 g	8.89 j	8.68 jkl

Means with similar letters in each column are not significantly different according to LSD Test

Table 6. Growth duration (days since sowing to harvest) of four rapeseed cultivars under four levels of paraquat application (Numbers in the parentheses are growth degree-day equivalents)

	Rates of paraquat (lit.ha^{-1})			
Rapeseed cultivars	Control	0.2	0.4	0.8
Hyola308	213 (1367.6)	208 (1196.2)	206 (1151.9)	205 (1130.5)
Hyola401	215 (1405.0)	210 (1238.5)	208 (1196.2)	207 (1173.8)
Hyola420	214 (1386.1)	212 (1279.1)	210 (1238.5)	209 (1218.2)
RGS003	216 (1421.5)	210 (1238.5)	209 (1218.2)	212 (1279.1)

Analysis of variance showed a significant effect of paraquat on grain yield, oil content and 1000 grain weight of rapeseed cultivars (Table7). Paraquat applied at 0.4 lit.ha^{-1} produced the highest grain yield (2370 kg.ha^{-1} in Hyola420) compared to the plots treated with 0.8 and 0.2 lit.ha^{-1} paraquat and the non-treated control plot (2289, 2171 and 2159 kg.ha^{-1}, respectively). The highest grain yield was obtained with 0.4 lit.ha^{-1} of paraquat application for all rapeseed cultivars. Averaged over four levels of paraquat application, Hyola420 outperformed the rest of cultivars in term of grain yield (Table 8). Given that paraquat application had no negative effect on rapeseed grain yield and enhanced grain moisture reduction rate, it seems that the rapid drydown of the shoot may cause siliques opening and grain shattering which may lead to yield reduction with higher doses (0.8 lit.ha^{-1}). The highest oil content (40.1%) was obtained with 0.2 lit.ha^{-1} of paraquat application in Hyola308 (regardless of 42.25% in control Hyola420) (Table 8). Hyola420 with 0.4 lit.ha^{-1} of paraquat, with 37% oil content and 2370 kg.ha^{-1} grain yield, produced 877 kg oil ha^{-1}, outyielding all treatments except for the non-treated Hyola420 (912 kg.ha^{-1}). The growth of the siliques start prior to grain development in rapeseed and the grains reach 35% of final dry weight when the siliques reach their maximum length. The dependence of the grain on silique after physiological maturity reduces gradually. Therefore the application of desiccants may not impose adverse effects on grain yield and quality of rapeseed (Darwent, *et al.,* 2000). Maximum 1000 grain weights were observed with 0.8 lit.ha^{-1} of parauat in Hyola401 and Hyola420 (4.30 and 4.20 g, respectively). Eastin (1980) found no adverse effects of paraquat, ghlyphosate and sodium chlorate application on 1000 grain weight of rice.

Table 7. Analysis of variance of grain yield, oil content and 1000 grain weight of four rapeseed cultivars under four levels of paraquat application

		Mean of Squares (MS)		
S.O.V	df	Grain yield	Oil content	1000 Grain weight
Rapeseed cultivars	3	145736.5**	14.54**	0.858**
E_a	6	191.354	0.42	0.032
Paraquat rates	3	82065.17**	20.93**	0.155**
Cultivar*Paraquat	9	2033.55**	6.65**	0.138**
E	24	101.00	0.16	0.003
C.V (%)		5.3	1.08	1.43

*, **: Significantly different at P=0.05 and P=0.01 probability levels, respectively; ns: Non significant

Table 8. Mean comparison of grain yield, oil content and 1000 grain weight of four rapeseed cultivars under four levels of paraquat application

	Rapeseed cultivars															
	Hyola308				Hyola401				Hyola420				RGS003			
	Rates of paraquat (lit.ha^{-1})				Rates of paraquat (lit.ha^{-1})				Rates of paraquat (lit.ha^{-1})				Rates of paraquat (lit.ha^{-1})			
Traits	Control	0.2	0.4	0.8	Control	0.2	0.4	0.8	Control	0.2	0.4	0.8	Control	0.2	0.4	0.8
Grain yield (kg.ha-1)	1766^{kl}	1782^{k}	1943^{i}	1801^{j}	2056^{h}	2075^{g}	2256^{c}	2089^{f}	2159de	2171^{d}	2370^{a}	2289^{b}	1418^{op}	1428^{o}	1558^{m}	1450^{n}
Oil content (%)	38.63^{e}	40.10^{b}	39.38^{bc}	37.79^{fg}	39.34^{bcd}	35.10^{o}	34.99^{op}	36.24^{lm}	42.25^{a}	37.58^{fghi}	36.95^{ij}	35.84^{lmn}	38.1^{ef}	37.71^{fgh}	36.93^{jk}	36.38^{jkl}
1000 grain weight (g)	4.00^{g}	3.34^{op}	3.51^{mn}	3.83^{o}	4.14^{bcd}	3.74^{jkl}	4.12^{bcdef}	4.30^{a}	4.19^{bc}	4.13^{bcde}	3.96^{gh}	4.20^{b}	3.78^{jk}	3.79^{j}	3.93^{ghi}	3.55^{m}

Means with similar letters in each row are not significantly different according to LSD Test

Results showed that paraquat application had no adverse effect on the major fatty acid content of rapeseed cultivars. Residue analysis of paraquat in the rapeseed cultivars grain showed that the minimum and maximum residue rates were related to 0.2 lit.ha^{-1} and 0.8 lit.ha^{-1} of paraquat in Hyola308 (2.61±0.24 and 10.65±0.97 mg kg^{-1}, respectively) (Table 9), that was less than paraquat LD_{50} (148 mg.kg^{-1} of living weight of organism) (Ecobichon, 2001 and Lock and Wilks, 2001). Although the threshold toxicity level for human is considered to be 0.01 to .001 mg/m^3

compared to that in animals, but the paraquat residue level in grain or oil was still 10 to 100 times lower than the minimum toxicity level (Lock and Wilks, 2001). Sims (1983) reported that the mean residues of diquat and paraquat in grains after application on rapeseed were negligible (Marchiori, 2002). Akinloye *et al.*, (2011) also reported that the paraquat residue in different vegetables when applied at the beginning of vegetative growth stages was trace and could be ignored.

Table 9. Major fatty acids content of four rapeseed cultivars under four levels of paraquat application

	Major fatty acids (%)		
Rapeseed cultivars / Rates of paraquat	Oleic acid (18:1)	Linoleic acid (18:2)	Linolenic acid (18:3)
Hyola308 / (0.2 $lit.ha^{-1}$)	64.9339	17.5726	8.3554
Hyola308 / (0.4 $lit.ha^{-1}$)	64.2192	18.4320	7.5523
Hyola308 / (0.8 $lit.ha^{-1}$)	64.2456	17.7935	6.8452
Hyola401 / (0.8 $lit.ha^{-1}$)	66.3490	16.9653	8.6076
Hyola420 / (0.8 $lit.ha^{-1}$)	56.4076	17.4207	7.8158
RGS003 / (0.8 $lit.ha^{-1}$)	60.9559	20.7242	9.0693
Control	65.0000	20.1234	8.2143

Table 10. Mean residues of paraquat in the grains of four rapeseed cultivars under four levels of paraquat application

Residues of paraquat ($mg.kg^{-1}$)			
	Rates of paraquat		
Rapeseed cultivars	0.2 $lit.ha^{-1}$	0.4 $lit.ha^{-1}$	0.8 $lit.ha^{-1}$
Hyola308	2.61 ± 0.24	5.62 ± 0.51	10.65 ± 0.97
Hyola401	-	-	9.7 ± 0.65
Hyola420	-	-	9.33 ± 0.28
RGS003	-	-	9.54 ± 0.33

CONCLUSION

Previous experiments have documented that the effectiveness of pre-harvest desiccants may have positive consequences by allowing more timely and efficient harvest (Jenks, *et al*., 2007 and Ross and Lembi, 1992). Monks and Sanders, (2004) reported the pre harvest desiccants application in a variety of crops in North Carolina, in America. Desiccation would permit more area to be harvested in a given time and provide enough time to plant the next crop. In the present experiment, all paraquat rates accelerated grain moisture reduction rate in rapeseed cultivars compared with controls (average; 2.86% vs. 1.75% day^{-1}) and promoted harvest time (5-7 days earlier than unsprayed plants). Grain moisture reduction rate was promoted 4 days after paraquat application along with an increase in ambient temperature and extension in day length. Stahlman, *et al*,. (2010) reported that the application of paraquat (4 $g.ha^{-1}$) promoted ripening in sunflower and the crop harvested 5-17 days earlier without any reduction in grain yield and grain weight. Similar results have been stated in soybean (Griffin and Bardeaux, 2011).

Overall assessment of grain yield and qualitative parameters measured in the present experiment revealed that rapeseed has adequate tolerance to pre-harvest application of paraquat. With the exception of a minor reduction in oil content (37% vs. 42%), application of paraquat had no adverse effect on grain yield or quality. Results of the present experiment showed that paraquat application may provide timely harvest and increase the speed of harvest operation. In addition, proper application of paraquat in the lowest concentration may lead to avoid its misuse.

It has been shown that paraquat produces positively charged ions that very quickly and tightly bind to negatively charged clay particles in the soil, rendering them totally inactivate. Thus paraquat has no soil activity. Although paraquat is persistent in soil, the strong sorption reduces availability of soil water to plant roots in the same way as for degrader microorganisms, and so phytotoxic effects do not normally occur. In addition, substantial photodegradation of paraquat does occur on the green surfaces of the plant. Paraquat is not generally transported to great distances in the plant and tends to kill the tissues to which it come in contact with, rendering little further movement (Vaughan, 2003). According to the data from the current experiment, it seems that, paraquat, in reduced doses, may be applied as a pre-harvest desiccant with no negative effects on grain yield and quality of rapeseed in the catchment area. Further experiments should focus on the persistence of paraquat in the soil, residues of paraquat in the shoot and root of the rapeseed plant and its effects on weeds present in the subsequent rice crop stand.

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اثر مصرف پیش از برداشت پاراکوات بر کاهش رطوبت دانه، عملکرد دانه و کیفیت ارقام کلزا (*Brassica napus* L.)

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چکیده

مصرف ترکیبات خشکاننده قبل از برداشت محصول کلزا، به برداشت به موقع و افزایش سرعت و کارایی عملیات برداشت محصول به عنوان کشت دوم پس از برنج کمک می‌کند. مواد خشکاننده مناسب نبایستی روی عملکرد و کیفیت محصول کلزا اثر منفی داشته باشند. این آزمایش به صورت کرت‌های خرد شده در سال زراعی 85-1384 در موسسه تحقیقات برنج کشور در رشت به اجرا گذاشته شد. ارقام کلزا شامل؛ هایولا 308، هایولا 401، هایولا 420 و RGS003 به عنوان عامل اصلی و تیمارهای محلول‌پاشی پاراکوات در 3 غلظت 0/2، 0/4 و 0/8 لیتر در هکتار (بر اساس ماده مؤثره 20 درصد) همراه با شاهد (بدون محلول‌پاشی) به عنوان عامل فرعی در نظر گرفته شدند. محلول‌پاشی بر اساس رطوبت 40 درصد دانه در یک سوم تحتانی گل‌آذین ساقه اصلی در اوایل اردیبهشت تا اواخر ماه انجام شد. نتایج نشان داد که غلظت 0/8 لیتر در هکتار پاراکوات بیشترین سرعت کاهش رطوبت دانه (2/94 درصد در روز) را نسبت به شاهد (1/75 درصد در روز) داشته و بدون تأثیر منفی بر عملکرد دانه، باعث تسریع در برداشت محصول (7- 5 روز زودتر از شاهد) گردید. بیشترین عملکرد دانه در غلظت 0/4 لیتر در هکتار پاراکوات (2370 کیلوگرم در هکتار در رقم هایولا 420 نسبت به شاهد با میانگین 2159 کیلوگرم در هکتار) به دست آمد. نتایج همچنین نشان داد که مصرف پاراکوات هیچ اثر منفی بر میزان روغن دانه و اسیدهای چرب آن نداشت. میزان اسید اولئیک در رقم هایولا 308 در غلظت‌های 0/2، 0/4 و 0/8 لیتر در هکتار پاراکوات و شاهد به ترتیب 64/93، 64/22، 64/25 و 65 درصد بود. میانگین باقی‌مانده پاراکوات در غلظت‌های پایین تا متوسط پاراکوات، به ترتیب 5/62 و 2/61 میلی‌گرم بر کیلوگرم مشاهده شد که همه آنها پایین‌تر از آستانه سمیّت پاراکوات بودند. بر اساس نتایج این آزمایش می‌توان اظهار داشت که مصرف پاراکوات در غلظت پایین، می‌تواند به عنوان یک خشکاننده مناسب در کشت کلزا مورد استفاده قرار داده شود.