HERBICIDES AND DESICCATION TIMES ON BUCKWHEAT PRODUCTIVITY AND GERMINATION

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ABSTRACT: Buckwheat (Fagopyrum *esculentum*) fits very well in the soybean (harvested in the 2nd fortnight of February) and wheat off-season (sown in the 2nd fortnight of May), standing out for being a rustic and short cycle plant that produces gluten-free flour. However, the crop presents uneven maturation and a natural dehiscence habit, which can result in production losses. In this context, this work aimed to evaluate herbicides and desiccation times on the buckwheat yield, productivity and germination components. The experimental design used was that of random blocks, with three replicates in a factorial scheme with split plots. Factor A was composed of 4 desiccation times (1st application with 70% of mature grains in the main stem and the others successively with three days of interval) and factor B was composed of two herbicides (ammonium glufosinate and paraquat). Yield, mass of one thousand grains and number of grains per plant components did not differ between herbicides or desiccation times. Desiccation at 69 days after emergence with ammonium glufosinate showed the highest buckwheat productivity and germination rate. For herbicide paraquat, there was no difference in productivity between application at 66 and 69 days after emergence; however, at 69 DAE, the germination rate was lower (80%).

KEYWORDS: Dehiscence; Ammonium Gluphosinate; Paraquat; Desiccation time.

HERBICIDAS E ÉPOCAS DE DESSECAÇÃO NA PRODUTIVIDADE E GERMINAÇÃO DE TRIGO MOURISCO

RESUMO: O trigo mourisco, *Fagopyrum esculentum*, se ajusta muito bem na entressafra soja (colhida em 2ª quinzena de fevereiro) - trigo (semeadura na 2ª quinzena de maio), destacando-se por ser uma planta rústica, de ciclo curto e produzir uma farinha sem glúten. No entanto, a cultura apresenta maturação desuniforme e hábito de deiscência natural, fato que pode resultar em perdas na colheita. Nesse contexto, o trabalho teve como objetivo avaliar herbicidas e períodos de dessecação sobre os componentes de rendimento, produtividade e germinação do trigo mourisco. O delineamento experimental utilizado foi o de blocos ao acaso, com três repetições, em esquema fatorial com parcelas subdivididas. O fator A foi composto por 4 épocas de dessecação (1ª aplicação com 70% dos grãos maduros na haste principal e as demais sucessivamente a cada três dias de intervalo) e, o fator B, por dois herbicidas (glufosinato de amônio e paraquat). Os componentes de rendimento, massa de mil grãos e número de grãos por planta não diferiram entre os herbicidas ou épocas de dessecação. A dessecação aos 69 dias após emergência, com glufosinato de amônio, apresentou a maior produtividade e a maior taxa de germinação do trigo mourisco. Para o herbicida paraquat, não houve diferença para produtividade entre a aplicação aos 66 e 69 dias após emergência, no entanto, aos 69 DAE a taxa de germinação foi inferior (80%).

PALAVRAS CHAVE: Deiscência; Glufosinato de amônio; Paraquat; Período de dessecação.

INTRODUCTION

Buckwheat (*Fagopyrum esculentum*) is a plant of the Polygonaceae family and, despite being called wheat, it is not related to wheat (*Triticum aestivum* L.). In addition, it is a rustic and short-cycle plant, which has been standing out in several countries due to its dietary and medicinal potential (Quequeto et al., 2018).

Buckwheat is an excellent crop option as second summer crop, adapted to any hot climate region, and can be used as grains, seeds or even as cover crop (Wendler et al., 2016).

Simonetti et al. (2016) emphasize that the crop presents rapid development and easy handling, being considered an excellent alternative for both grain production and forage production.

Buckwheat has indeterminate growth habit and short cycle (BJORKMAN and SHAIL, 2010), initiating flowering within 3 to 6 weeks and fully maturing within 11 to 12 weeks (Bjorkman et al., 2009), and these 11 weeks correspond to 77 days after emergence.

According to Quequeto et al. (2018) and Sytar et al. (2014), buckwheat has been highlighted in recent seasons, with great demand from consumers, attributed to its nutritional power and to its absence of gluten. In addition, since it is one of the few options for grain cultivation in the soybean-wheat off-season with economic potential, it is able to provide, in addition to an option for crop rotation, extra income in a period of the year when agricultural areas are usually in fallow (Pavek, 2016).

Among the limitations of buckwheat cultivation, grain losses due to the problem of natural dehiscence and indeterminate growth habit stand out, with consequent uneven flowering and maturation (Funatsuki et al., 2020).

Knowing that the desiccation time can influence the productivity and consequently the profitability of crops, as well as the potential of using the grain as seed, it is necessary to study the best desiccation time for the producer to succeed in buckwheat cultivation. Therefore, the aim of this work was to evaluate the buckwheat yield, productivity and germination components as a function of the application of different herbicides and different times.

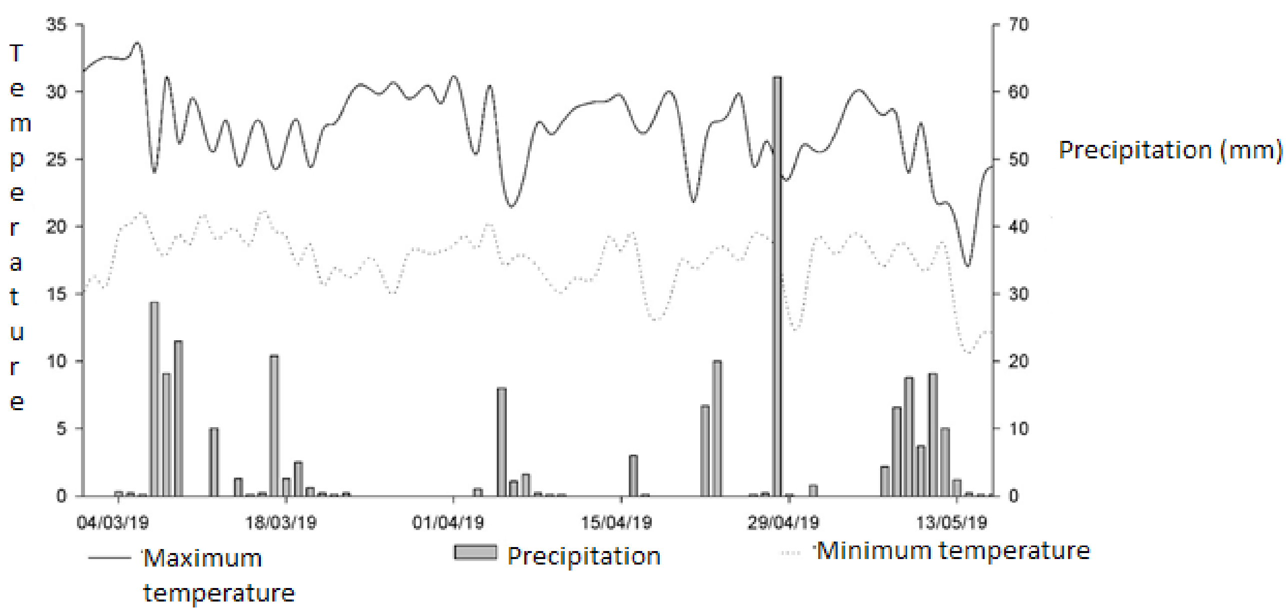
MATERIAL AND METHODS

Location and characterization of the experimental area

The field experiment was carried out at the Annual Cultures Teaching and Research Unit of the Federal Technological University of Paraná (UTFPR), Campus of Dois Vizinhos– Paraná (25º42'4'' S and 53º5'43'' W).

The site has average altitude of 540 m a.s.l., with soil classified as Distroferric Red Latosol (Bhering et al., 2008). The predominant climate is mesothermal humid subtropical (Cfa), with average annual temperatures of approximately 20 °C (Alvares et al., 2013) and average annual precipitation between 1,800 and 2,000 mm (IAPAR, 2019). Minimum and maximum temperature and precipitation data observed during the conduction of the study are shown in Figure 1.

Figure 1. Precipitation, maximum, minimum and average temperature, recorded during the study period, Dois Vizinhos, 2019. Source: INMET, (2019).



Experimental design

The experiment was carried out in a randomized block design, with three replicates in a 4 x 2 factorial scheme, with split plots. The main plot consisted of the desiccation time, defined considering the point of 70% of mature grains on the main stem, for the first desiccation (time 1: 63 days after buckwheat emergence (05/07/19); time 2: three days after the first desiccation (05/10/19); time 3: three days after the second desiccation (05/13/19) and time 4: three days after the third desiccation (05/16/19), being this division of times every 3 days in order to divide the period of grain formation. In the subplot, different herbicides were applied (herbicide 1: ammonium glufosinate (200 g L^{-1}) and herbicide 2: paraquat (200 g L^{-1}).

The experiment consisted of 24 subplots. Each subplot consisted of 12 buckwheat cultivation rows with 5 meters in length, totaling 25 m². For evaluations, the 4 central rows with 3 meters in length were considered, originating observation units (OU) with 12 m².

Conducting the experiment

The experiment was implemented after the soybean harvest on 03/01/2019, early March, where sowing was carried out with a continuous flow seeder. Base fertilization was not performed due to the good fertility parameters of the experimental site. For sowing buckwheat, 50 kg of seeds per hectare was used.

For cultural treatments, some observations were performed in the area to analyze whether weed control would be necessary, as well as weekly monitoring of pests and diseases and, if this experiment occurred with high incidence of pests, the use of insecticides would be required. However, it was observed that the use of herbicides and insecticides was not necessary.

In order to carry out this work, specific methodology was not used, but what is considered standard for this type of field work.

On May 7, after almost complete maturation of the buckwheat crop, which reached 70% of mature grains and 63 days after emergence, the first desiccation was performed. Application was carried out using a 20-liter backpack sprayer, with volume of 2 L/ha^{-1} of ammonium glufosinate and 2L/ha^{-1} of paraquat with application solution of 150 L/ha^{-1}.

After desiccation, 6 days were allowed for the use of paraquat and 11 days for ammonium glufosinate for herbicides to take effect and completely desiccate the buckwheat, and then evaluations and harvest were carried out.

As the effect of herbicides are different, it was necessary to wait different periods for harvest, simulating a mechanized harvest, observing whether there was interference effect on the final result, which is intrinsic to the treatment.

Variables analyzed

As buckwheat yield components, the following parameters were evaluated: population, amount of grains per plant, number of inflorescences per plant, mass of one thousand grains, productivity (kg ha^{-1}), and grain germination test was also performed. For population (plants ha^{-1}), at the harvest time, the number of plants present in each OU was counted, and the value was extrapolated to hectare. The grain yield per plant was measured from the arithmetic mean of counting the number of grains of 4 plants at random per OU. The number of inflorescences per plant was measured by counting the number of inflorescences of 4 plants at random per OU. For productivity (kg ha^{-1}), plants were collected from OUs, cutting them close to the ground and stored in plastic bags for later manual threshing. The grain sample obtained was weighed on a precision scale, measuring moisture and correcting the sample weight for moisture content of 13%, and then the value was extrapolated to hectare. For mass of 1000 grains (g), two samples of 100 grains were weighed, which were weighed and the arithmetic mean between values was calculated. Grain moisture was corrected to 13% and the value multiplied by 10.

Germination (%)

Germination was evaluated in the laboratory according to methodology described in the Rules of Seed Analysis (RAS) (BRASIL, 2009). Substrates on paper, paper roll and between paper were used, being stored in biochemical oxygen demand (BOD) at temperature between 20º to 30º C, being performed the initial count on the 4th day and final count on the 7th day after implantation. Fifty seeds per each herbicide were used in 2 germitest papers with amount of water 2 times greater than the weight of papers.

Statistical analysis of data

Data were tabulated and submitted to analysis of variance (ANOVA) to verify whether there was significant effect between treatments, using the F test, at 5% probability (p<0.05). If there was significant effect, comparison of means test was applied, and the Tukey test at 5% probability. Analyses were performed with the help of the Sisvar 5.6 statistical software (Ferreira, 2014).

RESULTS AND DISCUSSION

Table 1 shows that there was interaction between factors (application times and herbicides) only for variables grain yield and yield per plant. In addition, when analyzing each factor in isolation, it was found that the number of inflorescences shows significance as a function of desiccation time (Table 1).

Table 1. Summary of the analysis of variance for buckwheat variables (*Fagopyrum esculentum*), Federal Technological University of Paraná (UTFPR), Campus of Dois Vizinhos – PR, 2020.

Cause of variation	DF	Population (plants ha^{-1})	Number of inflorescences per plant	Number of grains per plant
Block	3	1.4334	24,2487	3,312,4453
Time (EP)	4	3.7645 ^{ns}	76,1937*	2,295,0694 ^{ns}
Error 1	6	4.1854	14,6402	4,611,2543
Herbicide (HE)	1	909306129.51^{ns}	1,8704 ^{ns}	429,2604 ^{ns}
He*Ep	3	1.3971 ^{ns}	18,3093 ^{ns}	713,9270 ^{ns}
Error 2	8	1.2106	18,2945	1,557,0572
Total corrected	23	----	-----	-----
CV 1 %		16,18	11.74	47.78
CV 2 %		8,70	13.13	27.76
Overall average		399.779,04	32.58	142.13
Cause of variation	DF	Mass of one thousand grains	Productivity (kg ha^{-1})	Productivity per plant
Block	2	0.0044	4,370,0099	0.0223
Time (EP)	3	0.0433 ^{ns}	90,311,0593 *	0.0937*
Error 1	6	0.0100	9,654,0593	0.0085
Herbicide (HE)	1	0.00008 ^{ns}	11,964,7401 ^{ns}	0.0041 ^{ns}
He*Ep	3	0.0097 ^{ns}	31,231,8663*	0.0309 *
Error 2	8	0.0030	3,680,1777	0.0073
Total corrected	23	-----	-----	----
CV 1 %		6.15	12.69	6.62
CV 2 %		3.41	7.84	6.14
Overall average		16.3	773.98	1.39

Legend – DF (Degree of freedom); CV (Coefficient of variation); HE (Herbicide); EP (Time)

It was observed that the final plant stand obtained was 40 plants per m^2 (Table 1). According to Fang (2018), the population density recommendation for buckwheat is 40 plants per m^2.

It was observed that the average population obtained in the experiment was below results found in some literatures, a fact that may have resulted in lower productive yield. Xiang et al. (2016) used buckwheat population densities ranging from 60 plants per m^2 to 150 plants per m^2.

As reported in Table 1, there was an effect of the desiccation time on variable number of inflorescences. It was observed that the desiccation time 2 presented, on average, 8.55 more inflorescences than desiccation time 3 (Table 2).

Table 2. Number of inflorescences per buckwheat plant (*Fagopyrum esculentum*) as a function of herbicide and desiccation time, Federal Technological University of Paraná (UTFPR), Campus of Dois Vizinhos – PR, 2020.

Number of inflorescences per plant	
TIME 1 63 DAE*	33.35 ab
TIME 2 66 DAE	36.25 a
TIME 3 69 DAE	27.70 b
TIME 4 72 DAE	33.05 ab

* Days after emergency. Means followed by different lowercase letters in the column differ statistically by the Tukey's test at 5% probability.

Despite the statistical differences in the number of inflorescences per plant, for the number of grains per plant and mass of one thousand grains, no effect of the evaluated factors was observed, showing average values of 142.13 grains per plant and 16.3 grams, respectively (Table 1).

The days of differences between desiccation times were not enough to observe difference in the number of grains and in the mass of one thousand grains, nor the evaluated herbicides, ammonium glufosinate and paraquat both being of contact. In contrast, the number of plants for sampling can also be allocated as a possible cause of the non-statistical difference for variables.

Table 3 shows the interaction between factors reported in Table 1. Regarding the herbicides applied, it was observed that ammonium glufosinate exhibits higher grain yield when applied at time 2 (925.67 kg ha^{-1}) (Table 3). However, when using paraquat, higher grain yields were observed in times 2 and 3, 920.65 and 950.38 kg ha^{-1}, respectively.

Table 3. Yield of buckwheat (*Fagopyrum esculentum*) grains as a function of herbicide and desiccation time, Federal Technological University of Paraná (UTFPR), Campus of Dois Vizinhos – PR, 2020.

Time	Ammonium glufosinate		Paraquat	
TIME 1 63 DAE*	715.00	bA	691.68	bA
TIME 2 66 DAE	925.67	aA	920.65	aA
TIME 3 69 DAE	691.25	bB	950.38	aA
TIME 4 72 DAE	674.71	bA	622.53	bA

* Days after emergence. Means followed by different uppercase letters in the row and lowercase in the column differ statistically by the Tukey's test at 5% probability.

For ammonium glufosinate, desiccation time 2 (66 DAE) showed higher grain yield than the others. In time 1 (63 DAE), grains were not yet formed, in times 3 (69 DAE) and 4 (72 DAE), the plant was already in a more advanced maturation stage, and it is possible that there were losses by natural dehiscence.

For paraquat, desiccation times 2 (66 DAE) and 3 (69 DAE) showed higher productivity than the others. Taking into account that possibly time 1 (63 DAE) with 70% of mature grains on the main stem, grains were not formed and for time 4 (72 DAE), there were losses due to natural dehiscence.

Among the desiccation times of products, it was observed that only time 3 for paraquat application (950.38 kg ha^{-1}) promoted higher productivity in relation to the application of ammonium glufosinate (691.25 kg ha^{-1}) (Table 3). This factor may be linked to the natural buckwheat dehiscence, where, due to the time that ammonium glufosinate was applied, buckwheat remained 6 days longer in the field, which resulted in the natural plant threshing. According to Morishita et al. (2020), natural dehiscence is one of the most important causes of buckwheat yield loss, due to the fact that grains easily fall off the stem, and using cultivars resistant to natural dehiscence is necessary.

According to Pavek (2016), buckwheat plants begin to flower within 3 to 6 weeks after sowing and flower continuously for several weeks. Seeds mature 10 days after flowering and fall off the plant shortly after maturation, which reduces yield and causes potential problems for volunteer plants the following year.

Popovic et al. (2013) observed average buckwheat productivity yield of 2,156 kg ha^{-1} in the conventional cropping system in studies conducted between 2010 and 2012 in Serbia. These yields ranged from 1215 kg ha^{-1} (2012) to 2996 kg ha^{-1} (2010) and this difference is due to the different climates of each year, where in 2012, buckwheat ended up by suffering from low rainfall, about 60 % less than in the year 2010.

Buckwheat grain yield ranges in other countries have been reported to be 1.46 - 1.59 t ha^{-1} in Turkey (KARA, 2014), while around 1.2-1.7 t ha- in the US 1 (Björkman, 2010) and 0.76-1.53 t ha^{-1} in Italy (Brunori et al., 2005). Thus, the average productivity (773.98 kg) (Table 1) found in this work is lower than that found in other countries. This result may have occurred due to the lack of ideal conditions for the culture, since it is a summer culture and was implanted in the autumn, where low temperatures occur, in addition to having a possible relationship of low population in the results of lower grain productivity.

According to Da Silva et al. (2002), earlier buckwheat sowing times, between June and September, lead to higher grain yields, reaching average of 2900 kg ha^{-1} when compared to later times, between July and October, obtaining average productivity of 1950 kg ha^{-1}. The study was conducted with irrigated buckwheat cultivation in the dry season, in the cerrado region of Brazil with high temperatures, and the thermal sum from sowing to harvest, at time 1, was 1375.7 degree days and at time 2, 1531.6 degree days.

It is believed that the values found for the number of inflorescences per plant (Table 2) and the productivity per plant (Table 4) contributed for the variable grain yield to have greater effect with 923.16 kg ha^{-1} of average in time 2, with the use of ammonium glufosinate and paraquat herbicides, and, consequently, plants that had the lowest number of inflorescences had lower grain yield (Table 3).

Table 4. Productivity of buckwheat (*Fagopyrum esculentum*) plants as a function of herbicide and desiccation time, Federal Technological University of Paraná (UTFPR), Campus of Dois Vizinhos – PR, 2020.

Time	Ammonium glufosinate		Paraquat	
TIME 1 63 DAE*	1.31	aA	1.33	bcA
TIME 2 66 DAE	1.51	aA	1.48	abA
TIME 3 69 DAE	1.38	aB	1.61	aA
TIME 4 72 DAE	1.30	aA	1.19	cA

*Days after emergence. Means followed by different uppercase letters in the row and lowercase in the column differ statistically by the Tukey's test at 5% probability.

Table 4 shows the interaction observed for grain yield per plant. When ammonium glufosinate was applied, no effect on this variable was reported. However, when applying paraquat, it was observed that time 3 exhibits higher productivity per plant compared to times 1 (0.28 g) and 4 (0.42 g).

Furthermore, it was reported that in time 3, paraquat application promoted higher (0.23 g) grain yield per plant in relation to ammonium glufosinate (Table 4).

It is believed that this difference in productivity per plant between times and herbicides is due to the natural buckwheat dehiscence and also to the desiccation factor, because the fact that they are two different herbicides interferes with the final result.

It is observed in Table 5 that there was interaction between the factors under study for the germination of buckwheat seeds.

Table 5. Results of buckwheat (*Fagopyrum esculentum*) seed germination, Federal Technological University of Paraná (UTFPR), Campus of Dois Vizinhos – PR, 2020.

Cause of Variation	DF	Germination
Times	3	38.11^{ns}
Herbicides	1	57.72^{ns}
Ep*He	3	85.61*
Error	24	25.32^{ns}
Total Corrected	31	1036.71^{ns}
CV		5.85
Overall average		86.09

CV (Coefficient of Variation); DF (Degree of Freedom);

Table 6 shows the interaction observed for seed germination. When ammonium glufosinate was applied, no effect on this variable was observed. However, when paraquat was applied, it was observed that time 3 had greater germination compared to time 2.

Among application times, it was observed that the time 3 of ammonium glufosinate promoted greater germination in relation to time 3 of paraquat. There was no statistical difference between the other times.

According to Ponce (2019), for buckwheat, smaller seeds may be immature and with smaller reserve amounts, consequently, they do not provide sufficient support for germination.

According to Nishikawa (2019), a buckwheat seed to have good quality must be correctly stored and harvested under good conditions, including the seed maturity at the harvest time, which will also affect the germination quality.

As reported by Morishita et al. (2020), germinated buckwheat seeds have little market value, which further reinforces choosing the ideal harvest time.

Therefore, based on information in literature and on data obtained in the work, buckwheat germination with paraquat may have been negatively influenced, causing it to have lower germination as in time 3 (80%), Table 6.

Thus, both a systemic herbicide and a contact herbicide are efficient to carry out desiccation, when performed at the right time, because as shown in Table 6, time 3 of paraquat statistically differed from the other times.

The recommended time, which can be described as the best time for desiccation to be carried out, would be an intermediate time with 66 days after plant emergence up to about 69 days, because, based on data obtained, this is the time that higher yields can be reached, because plants will be at a more complete maturation stage for both systemic and contact herbicides.

Thus, mass of one thousand grain and number of grains per plant yield components did not differ between herbicides or desiccation times.

Since this work presented variations in results among yield components and because it is a new crop to be implanted in this region, further studies should be carried out in order to complement and better understand the effect caused by buckwheat desiccation. In these works, it is recommended to increase the sowing density and to perform base fertilization. In addition, it is suggested to increase the interval of days between desiccation times and also to conduct treatment without the application of herbicides.

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