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YIELD, SPECIFIC MASS AND COLORATION OF AZUKI SEEDS AFTER DESICCATION AND STORAGE

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ABSTRACT: Selection and dosage of desiccating herbicides may bring benefits to bean harvesting and its seed quality. This study aimed to assess yield, apparent specific mass and coloration of azuki bean seeds after pre-harvesting desiccation with different herbicides and doses and subsequent storing. In a first trial, we tested paraquat 400 (g ai ha^{-1}), ammonium glufosinate (400 g ai ha^{-1}), glyphosate (720 g ai ha^{-1}), flumioxazin (30 g ai ha^{-1}) and control. In second and third trials, we tested various doses of saflufenacil (0, 50, 75, 100, 150 and 200 g ai ha^{-1}) and flumioxazin (0, 20, 25, 30, 35 and 40 g ai ha^{-1}). All treatments were divided into plots and the dates of evaluation (at harvest and six months after harvest) into subplots with four replications. Even after storage, paraquat, ammonium glufosinate, glyphosate and flumioxazin had no effect on yield, specific mass or even coloration of azuki bean seeds. None of the doses of saflufenacil and flumioxazin impaired yield, specific mass and L* value of seeds, which is associated to lightness. Nevertheless, after six-month storage, the seeds desiccated with saflufenacil and flumioxazin lost color intensity and purity as function of the dose.

KEY WORDS: desiccating herbicides, post-harvest, ***Vigna angularis*** Willd.

INTRODUCTION

Seeds of any growing crop must be harvested just after physiological maturity; at this stage, they have high vigor, germination rate and a maximum dry matter accumulation (GUIMARÃES et al., 2012). On the other hand, they also are high in water content and the mother plants still carries green moist leaves and branches. Additionally, bean varieties show different growth habits and branching, which hinder harvesting by promoting damage to seeds (COELHO et al., 2012).

Preharvest chemical desiccation aims to control weeds and defoliate crops, anticipating harvest and improving harvester field performance (DALTRO et al., 2010). Nevertheless, some key factors must be considered including herbicide type and application rate to avoid drops in production and seed quality (TOLEDO et al., 2012).

Besides other postharvest techniques, bean seed quality can be maintained through storing. Regarding grains, quality loss during storage could be characterized by increased values of cooking time and coating hardness, as well as darkening and flavor changes (FARONI et al., 2006). When it comes to seeds, such losses are perceived through changes in physiological quality, sanitation, biochemistry, specific weight, color, among others (BLAIR et al., 2010).

Changes in coloration of agricultural products are associated to quality traits wanted or not by consumers. In the case of beans, grain brightness is preferred for consumption increasing commercial value of the product (RIBEIRO et al., 2008). The alterations in coloration of beans can be caused by leuco-anthocyanin oxidation catalyzed by air and light (RIBEIRO et al., 2014), being influenced by storage time. TEIXEIRA et al. (2011) observed bean darkening in cultivars as BRS Requinte, BRS Pontal, Pérola, CNFC 10467 and BRSMG Madrepérola-VC3, after a storage period of 180 days.

Recently in Brazil, a significant number of researches have been carried out with azuki beans (***Vigna angularis*** Willd.), primarily concerning farming practices (BASTOS et al., 2013) and post-

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harvest techniques (REZENDE et al., 2012). Adzuki beans are mainly produced and consumed in Asia, notably in China, Japan and Korea. In Brazil, there is no accurate statistical picture on the number of growers, production or cropped area. This grain is mainly consumed in Japanese colonies and priced well above the common bean (ALMEIDA et al., 2013).

Based on the foregoing, this study aimed to evaluate the effects of herbicides and doses applied as desiccant in preharvest seed on yield, apparent specific mass and coloring of stored azuki bean seeds.

MATERIAL AND METHODS

This research was carried out in the experimental field of the IF Goiano, Campus in Rio Verde, Goiás state, Brazil. The area lies at 17º 48’ 67’’ S and 50º 54’ 18’’ W geographical coordinates at an altitude of 754 m.

Local soil was classified as a dystroferric Red Latosol. Soil analysis at a 0-20 cm depth showed the following physico-chemical characteristics: pH ($CaCl_2$) of 5.2; P content of 11 mg dm^{-3}; K of 246 mg dm^{-3}; Ca of 5.77cmol$_c$ dm^{-3}; Mg of 1.63 cmol$_c$ dm^{-3}; Al of 0.03 cmol$_c$ dm^{-3}; V% of 64.6 and grain size distribution of 46, 10 and 44 dag kg^{-1} for clay, silt and sand, respectively. Figure 1 shows the climatological data measured during the experiment.

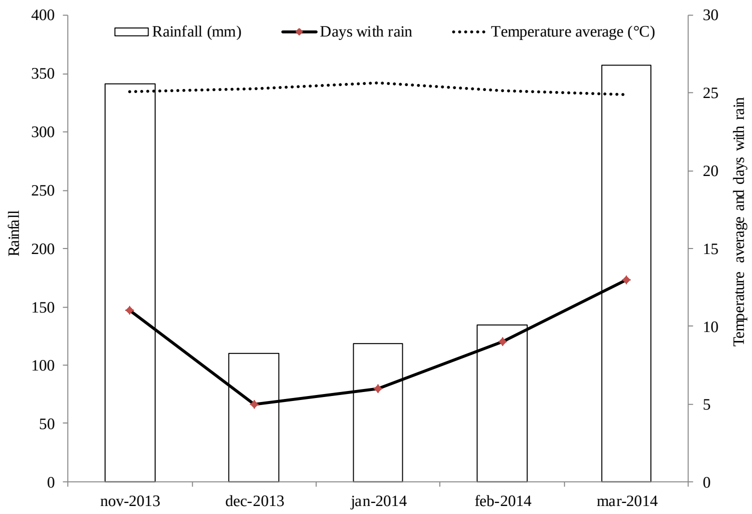

FIGURE 1. Rainfall, average temperature and number of days with rain from November 2013 to March 2014, in Rio Verde – GO, Brazil.

Three trials were conducted using a random block split-plot experimental design with four replications. In the first trial, we tested four herbicides in each plot: paraquat (400 g ai ha^{-1}), ammonium glufosinate (400 g ai ha^{-1}), glyphosate (720 g ai ha^{-1}), flumioxazin (30 g ai ha^{-1}) and control (without application); and subplots were two seed evaluation periods: at harvest time and 6 months after harvest (6 MA). In the second and third trials, we tested doses of two herbicides: saflufenacil (0, 50, 75, 100, 150 and 200 g ai ha^{-1}) and flumioxazin (0, 20, 25, 30, 35 and 40 g ai ha^{-1}); in both trials, doses represented the plots, and evaluation times the subplots (at harvest and after 6 months).

Each experimental unit had 20 m^2, consisting of eight 5-m planting rows. The floor area was constituted by the four central rows, discarding the other lines and a borderline of 0.5 m to the edges of each useful row.

The area was tilled by means of one plowing and two harrowings; and semi-mechanized sowing of beans was held in November 28, 2013. Eighteen seeds were sown per meter to a depth of 4 cm. Pre-planting fertilization was applied in sowing furrows, using 350 kg ha^{-1} of 02-20-18 formulation (N, P_2O_5, K_2O). After 25 days, topdressing was carried out applying 60 kg ha^{-1} N as urea.

Weed control was performed through manual weeding until canopy closure. As phytosanitary measures, pyraclostrobin (0.075 kg ha^{-1}) and thiamethoxam (0.060 kg ha^{-1}) were sprayed at 28 and 42 days after sowing, respectively.

Treatments were applied at 68 days after sowing (DAS) by the time of physiological maturity, when plants showed pods with mature coloration. The herbicides were applied using a backpack CO_2 pressurized sprayer with four nozzles of TT110°03 model, at a constant pressure of $2.5x10^5$ Pa and spray volume of 250 liters ha^{-1}.

At the time of harvest, which was performed manually, we evaluated the number of plants, seed yield within the floor area of each plot, besides seed coloration and apparent specific mass (M). From each plot useful area, ten plants were randomly removed for further counting on total number of pods per plant. We also sampled 200 pods, at random, to determine the number of seeds per pod and weight of 100 seeds, in duplicate.

After harvesting, seeds were packed into Kraft paper bags and stored at room conditions for six months. A digital data logger recorded storage environmental conditions as relative humidity (RH) and temperature (T) (precision of 0.1 °C and 5.0%); during the experimental period, we registered averages of 25.4 ± 3 °C and 67.3 ± 3%.

Seed yield and 100-seed weight were expressed at a 12% moisture level (wb) (ALMEIDA et al., 2013). Coloration was checked by direct reflectance reading of L system coordinates (brightness - black/ white), "a" (hue - green/ red) and "b" (hue - blue/ yellow) using a tristimulus color meter (illuminant 10º/ D65). The coordinate values were used to calculate chroma ($C= (a^2+b^2)^{1/2}$) defining color purity and intensity in addition to Hue angle (ºh arctang = (b/ a)), using the average of eight readings.

Data underwent variance analysis by the F test and when significant by the Tukey's test, adopting a significance level of 5%.

RESULTS AND DISCUSSION

The herbicides and doses had no effect on the variables NPP, SPP, 100-SW, SY and PP according to the main treatments and interactions. It demonstrates that bean plants have no variations on their production capacity, regardless herbicide and doses applied (Table 1).

The lack of significance found in the results may be because desiccant applications were held by the time bean seeds were at physiological maturity, when they reach a maximum dry matter accumulation (TOLEDO et al., 2012). These results are supported by observations made by KAPPES et al. (2012), who found no differences for yield components of common bean grown in winter and desiccated with paraquat at physiological maturity. Likewise, COELHO et al. (2012) found no differences for creole-bean yield when chemically desiccated during the physiological maturity.

TABLE 1. Number of pods per plant (NPP), seeds per pod (SPP), 100-seed mass (100-SW), seed yield (SY) and plant population - plants ha^{-1} (PP) of azuki bean (***Vigna angularis*** Willd.) as function of desiccating herbicide and doses, in Rio Verde – GO, Brazil.

Treatments	NPP[1/]	SPP	100-SW (g)	SY (kg ha^{-1})	PP (plants ha^{-1})
Desiccants					
Control[/1]	17.6 a	5.73 a	7.17 a	981.98 a	205.125 a
Paraquat	16.0 a	5.64 a	7.86 a	982.03 a	209.464 a
Ammonium glufosinate	16.5 a	5.88 a	8.11 a	961.12 a	210.267 a
Glyphosate	15.5 a	5.72 a	7.33 a	1.012.79 a	201.607 a
Flumioxazin	16.3 a	5.74 a	7.47 a	1.011.50 a	199.285 a
CV (%)	9.55	10.01	19.49	7.78	3.21
Saflufenacil doses					
0	16.40 a	5.58 a	8.92 a	726.79 a	209.791 a
50 g ai ha^{-1}	15.20 a	5.41 a	8.61 a	739.84 a	203.645 a
75 g ai ha^{-1}	15.65 a	6.27 a	8.36 a	734.18 a	207.083 a
100 g ai ha^{-1}	17.80 a	5.85 a	8.83 a	706.19 a	208.333 a
150 g ai ha^{-1}	18.50 a	5.96 a	8.72 a	740.91 a	211.250 a
200 g ai ha^{-1}	15.50 a	6.31 a	7.69 a	752.68 a	205.625 a
CV (%)	10.12	9.01	11.54	4.17	4.23
Flumioxazin doses					
0	15.95 a	5.63 a	6.89 a	981.13 a	197.500 a
20 g ai ha^{-1}	15.05 a	5.45 a	7.17 a	958.46 a	199.687 a
25 g ai ha^{-1}	15.25 a	5.69 a	7.59 a	1.016.72 a	200.208 a
30 g ai ha^{-1}	14.95 a	5.96 a	7.92 a	997.64 a	198.854 a
35 g ai ha^{-1}	15.45 a	5.58 a	7.70 a	959.92 a	200.104 a
40 g ai ha^{-1}	14.85 a	5.74 a	8.03 a	996.23 a	197.812 a
CV (%)	6.54	11.13	16.80	7.19	3.25

[1/] Means followed by the same letter in the columns are statistically similar by the Tukey's test at 5% significance. Experiment 1 - paraquat (400 g ai ha^{-1}), ammonium glufosinate (400 g ai ha^{-1}), glyphosate (720 g ai ha^{-1}), flumioxazin (30 g ai ha^{-1}) and one control (without application).

However, there are reports of effects on seed yield caused by desiccant applied soon after flowering (BÜLOW & CRUZ-SILVA, 2012). KAMIKOGA et al. (2009) found decreasing linear effect on grain yield of common beans with desiccation at 28, 33 and 43 days after full bloom, varying in approximately 140 kg ha-1. Notwithstanding, yield also undergoes the influences of genotype, crop season and environment as well as the interaction among them, which can be identified through adaptability and stability assessments (ROCHA et al., 2009).

The average yield found here was below the one found by BASTOS et al. (2013) also in Rio Verde – GO (Brazil), which was around 1,600 kg ha^{-1}, justified by droughts during grain formation and filling stages (Figure 1).

Table 2 shows that seed apparent specific mass was not influenced by the variation sources in the three trials. This variable may be affected by attack of insects and microorganisms, breathing process or significant variations in water content (SMANIOTTO et al., 2014). Therefore, our results demonstrated that seeds were properly stored at 12% moisture level (wb), being suitable for such environmental conditions. Table 2 also displays that seed coloring had no influence from saflufenacil and flumioxazin applications, varying only with storage period in trials 2 and 3.

TABLE 2. Apparent specific mass (M), coordinates *L*, *a* and *b*, chroma (C), and Hue angle (ºh) of azuki bean seeds (***Vigna angularis*** Willd.) as function of pre-harvest desiccant applications, in Rio Verde – GO, Brazil.

Treatments / Desiccants	M (kg m^{-3})	L	a	b	C	ºh
Control	762.50 a	26.80 a	12.41 a	9.67 a	15.74 a	0.66 a
Paraquat	760.83 a	25.72 a	11.05 a	9.22 a	14.41 a	0.70 a
Ammonium glufosinate	765.97 a	26.07 a	11.60 a	9.21 a	14.83 a	0.67 a
Glyphosate	776.11 a	26.51 a	12.56 a	9.66 a	14.85 a	0.65 a
Flumioxazin	774.17 a	26.40 a	12.69 a	9.50 a	15.16 a	0.64 a
Harvest	768.55 a	26.40 a	12.32 a	9.65 a	15.67 a	0.67 a
6 MAH	767.67 a	26.20 a	11.81 a	9.25 a	15.33 a	0.66 a
CV A (%)	2.56	3.03	7.45	7.16	4.79	8.55
CV B (%)	1.76	2.51	2.88	1.96	1.80	2.65
Saflufenacil doses						
0	778.06 a	26.69 a	12.41 a	9.51 a	15.64 a	0.65 a
50 g ai ha^{-1}	772.08 a	27.10 a	12.26 a	9.83 a	15.72 a	0.68 a
75 g ai ha^{-1}	779.17 a	26.08 a	12.23 a	9.31 a	15.38 a	0.65 a
100 g ai ha^{-1}	775.00 a	26.12 a	11.65 a	9.22 a	14.86 a	0.67 a
150 g ai ha^{-1}	778.89 a	26.77 a	11.47 a	9.73 a	15.05 a	0.70 a
200 g ai ha^{-1}	777.08 a	26.54 a	12.01 a	9.49 a	15.32 a	0.67 a
Harvest	781.32 a	26.81 a	12.02 a	9.76 a	15.49 a	0.68 a
6 MAH	779.89 a	26.28 a	11.99 b	9.26 b	15.16 b	0.66 b
CV A (%)	1.75	3.71	4.58	2.72	4.71	5.17
CV B (%)	1.51	3.60	3.66	4.89	3.23	4.62
Flumioxazin doses						
0	784.44 a	26.99 a	12.28 a	9.67 a	15.64 a	0.67 a
20 g ai ha^{-1}	788.47 a	26.46 a	12.69 a	9.52 a	15.87 a	0.64 a
25 g ai ha^{-1}	781.94 a	26.97 a	12.84 a	9.75 a	16.13 a	0.65 a
30 g ai ha^{-1}	776.81 a	26.85 a	12.30 a	9.48 a	15.53 a	0.66 a
35 g ai ha^{-1}	782.50 a	27.34 a	12.34 a	9.87 a	15.81 a	0.67 a
40 g ai ha^{-1}	789.94 a	26.96 a	12.74 a	9.76 a	16.06 a	0.65 a
Harvest	777.16 a	27.08 a	12.67 a	9.90 a	16.09 a	0.66 a
6 MAH	780.88 a	26.77 a	12.39 b	9.44 b	15.59 b	0.65 a
CV A (%)	1.75	3.71	4.58	2.72	2.91	4.22
CV B (%)	1.51	3.60	3.66	4.89	3.28	3.89

1/ Means followed by the same letter in the columns are statistically similar by the Tukey's test at 5% significance. Experiment 1 - paraquat (400 g ai ha^{-1}), ammonium glufosinate (400 g ai ha^{-1}), glyphosate (720 g ai ha^{-1}), flumioxazin (30 g ai ha^{-1}) and one control (without application). MAH = months after harvest.

The value of "L" is relevant information for beans because indicates grain clearness. For carioca type grain, clearer seed coats are associated with freshly harvested grains and fast cooking. It is said that cultivars with "L" values above 55 have a higher market value. On the other hand, less clarity is desirable by some consumers, implying in greater acceptance for black grains. The cultivars with "L" above 22 have a large percentage of purplish grains, which is related to inferior quality and longer cooking times (RIBEIRO et al., 2014).

There are several studies that assess the performance and quality of bean lineages, classifying them in special (white coat grains), red, cream, yellow, among others, as well as presence of stripes in other colors, splitting into medium to large grain sizes (BLAIR et al., 2010). These studies outlined as red lineages with "L" value from 24.5 to 43.7, therefore identifying lineages from light red - near 43.7 (Light Red Kidney, Red Kanner, Chinok and TB 02-24) up to dark red – near 24.5 (Montcalm, Xamego, Vermelho Graúdo and Dark Red Kidney) (RIBEIRO et al., 2014). Based on these values, azuki bean has a dark red color since "L" values are around 26.0 (Table 2).

The color variables “a”, “b”, hue angle and chroma were influenced by storage time, noting reduction in their values in the trials testing saflufenacil and flumioxazin doses (Table 2). The other characteristics remain unchanged. The variables "a", "b" Hue angle (°h) are indicative of hue and, chroma (C) defines color intensity; for these characteristics, there are no reports in literature referring to mean values, thus being used for color intensity determination (RIBEIRO et al., 2008). For the other grain classes, it was not found references in literature regarding color pattern. Therefore, these relationships are made empirically and subjectively (RIBEIRO et al., 2014). Regardless of seed moisture content at harvest time and drying temperatures, bean seeds tend to browning during storage (FARONI et al., 2006).

Considering that beans of different integument colors are sold at prices that exceed those of carioca and black beans, producing grains of different color classes might be an alternative to diversifying activities of high profitability family farming on both domestic and exports markets.

CONCLUSIONS

Desiccant applications at physiological maturity stage have no effect on yield and coloration of azuki bean seeds. Storage reduces integument color of azuki bean seeds, which is verified by decreasing chroma values.

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