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Field emergence of Marandu palisadegrass influenced by specific seed weight and sowing depth[1]

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ABSTRACT - Several species of harmful grass weeds were voluntarily brought in by man, mainly with the specific purpose of produce forage. These species compete with crops for physical area and environmental resources, can host pests and diseases, and interfere on harvesting. This work aimed to evaluate in field conditions, the effects of different specific seed weight and sowing depths on the emergence of the species *Urochloa brizantha* cv. marandú. It was adopted a randomized blocks design with four replications and the treatments arranged in a 6 x 3 factorial scheme, with six sowing depths (1.0, 2.0, 4.0, 8.0, 12.0 and 16.0 cm) and three specific seed weight (low, medium, and high). The treatment effects were evaluated by seedling emergence in field. The marandu-grass seedlings emerged until 12 cm depth, regardless of specific seed weight and year. Sowing depths between 1.0 and 4.0 cm depth have promoted the greater percentage of emergence, and the lowest average time and speed index for emergence of seedlings on field, regardless of the specific seed weight. High-specific weight seeds resulted in greater percentage of emergence on field, speed and synchronicity index of emergence of marandú-grass seedlings. Sowing depths higher than 1.0 cm induces a delay on marandú-grass propagation.

Key words: Vertical arrangement. Germination. Weeds. Seed physiological quality.

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INTRODUCTION

Weeds are one of the ecological factors that most affect the agricultural economy permanently because, in addition to causing physiological damage to crops, their control also entails expenses that increase the production cost (Monquero *et al*., 2015; Santos *et al*., 2019). It should be noted that many of the problematic grass weed species currently found in Brazil were voluntarily introduced by man for economic purposes, mainly for fodder (Silva Junior *et al*., 2023).

Weed species, such as those of the *Urochloa* genus, compete with crops for physical space and environmental resources, can be hosts to pests and diseases, interfere with the harvesting process, which increases the formation and recovery time of other forage grasses and can also decrease the acceptability and palatability of animals, making it necessary to use alternative methods to manage these weeds in the field (Lourenço *et al*., 2019; Marchi *et al*., 2020).

Seed germination is regulated by the interaction of environmental conditions with their state of physiological fitness, with each plant species requiring a set of environmental resources necessary for the germination of its seeds, such as the availability of water, light, temperature, and the depth at which they are found in the soil profile (Zuffo *et al*., 2014). Therefore, germination in these different conditions and knowledge of the emergence capacity of seedlings from seeds located at different depths in the soil can help in weed management by adopting methods that reduce or prevent their occurrence, such as the use of mechanical control associated or not with chemical control (Orzari *et al*., 2013).

It is known that the vast majority of weeds reproduce by seed, and the success of this is due to the ability to distribute germination over time (dormancy and longevity in the soil) and space (dispersal) (Grime, 2006). However, these species that propagate by seeds have evolved to produce more seeds, to the detriment of their specific weight, thus creating mechanisms to accelerate the germination process at suitable depths since the reduced availability of seed reserves would not be sufficient to support the growth of the seedling until emergence (Souza *et al*., 2021).

Environmental conditions can also influence the quantity and specific weight of seeds. Thus, the same weed species can produce seeds with different specific weights (Araldi *et al*., 2013; Carvalho; Nakagawa, 2012). The quality of these seeds is determined by physical, genetic, health, and physiological attributes since the germination processes and initial seedling development are directly linked to these attributes (Marques *et al*., 2023).

It should be noted that studies relating the influence of specific seed weight and sowing depth on the emergence of weeds under field conditions have been little explored but are necessary due to the great importance of these species and the limited information related to the production of seeds from these plants. This understanding is useful for modeling the potential invasion of weed species and providing subsidies for developing and adopting relevant management practices, reducing or preventing the appearance of undesirable species in agricultural areas.

This study aimed to evaluate, under field conditions, the effects of different specific seed weights and sowing depths on the emergence of Marandu palisadegrass [*Urochloa brizantha* (Hochst. ex A.Rich.) R.D. Webster cultivar Marandú].

MATERIAL AND METHODS

The field trial phase of this research was represented by studies conducted over two years and in two different locations.

The first study was conducted in 2021 in an experimental area belonging to the Department of Plant Production, Faculty of Agricultural and Veterinary Sciences, UNESP, in Jaboticabal SP, at 21°14’43.42” S and 48°17’32.8” W, and an altitude of 583 m. The second study was conducted in 2022 in an area located in the experimental field of the Federal University of Mato Grosso, Campus of Araguaia, in Barra do Garças MT, at 15º52’2’’ S and 52º18’51” W, and an altitude of 318 m.

The climate of Jaboticabal SP, according to the Köppen system, is classified as Cwa-type (subtropical mesothermal with dry winter), with average rainfall between 1100 and 1700 mm per year and average temperatures of the hottest month of 22 ºC and the coldest month of 18 ºC. The climate of Barra do Garças MT is Aw-type (tropical with dry winter), characterized as having average temperatures above 27 ºC in the hottest months, average temperatures above 18 ºC in the coldest months, and average annual rainfall between 1000 and 1500 mm. The climatological data observed during the period in which the experiments were conducted, in both regions and years, is shown in Figure 1.

The experimental design was randomized blocks with four replications arranged in a 6 x 3 factorial scheme, with six sowing depths (1.0, 2.0, 4.0, 8.0, 12.0, and 16.0 cm deep) associated with three specific seed weights, considered low, medium, and high.

The studies in 2021 and 2022 were conducted between 15/01 and 11/02, the period between sowing and the end of emergence. Preparation of the areas began 15 days before sowing, with desiccation for total control of the existing vegetation, using the herbicide glyphosate at a dose of 1,080 g a.e. ha^{-1}, with subsequent plowing with a disc plow, ending with two harrowing operations: one heavy and the other light, for total incorporation of the plant remains.

Composite soil samples from both years were collected and sent for laboratory analysis, and their chemical and physical characteristics are shown in Tables 1 and 2.

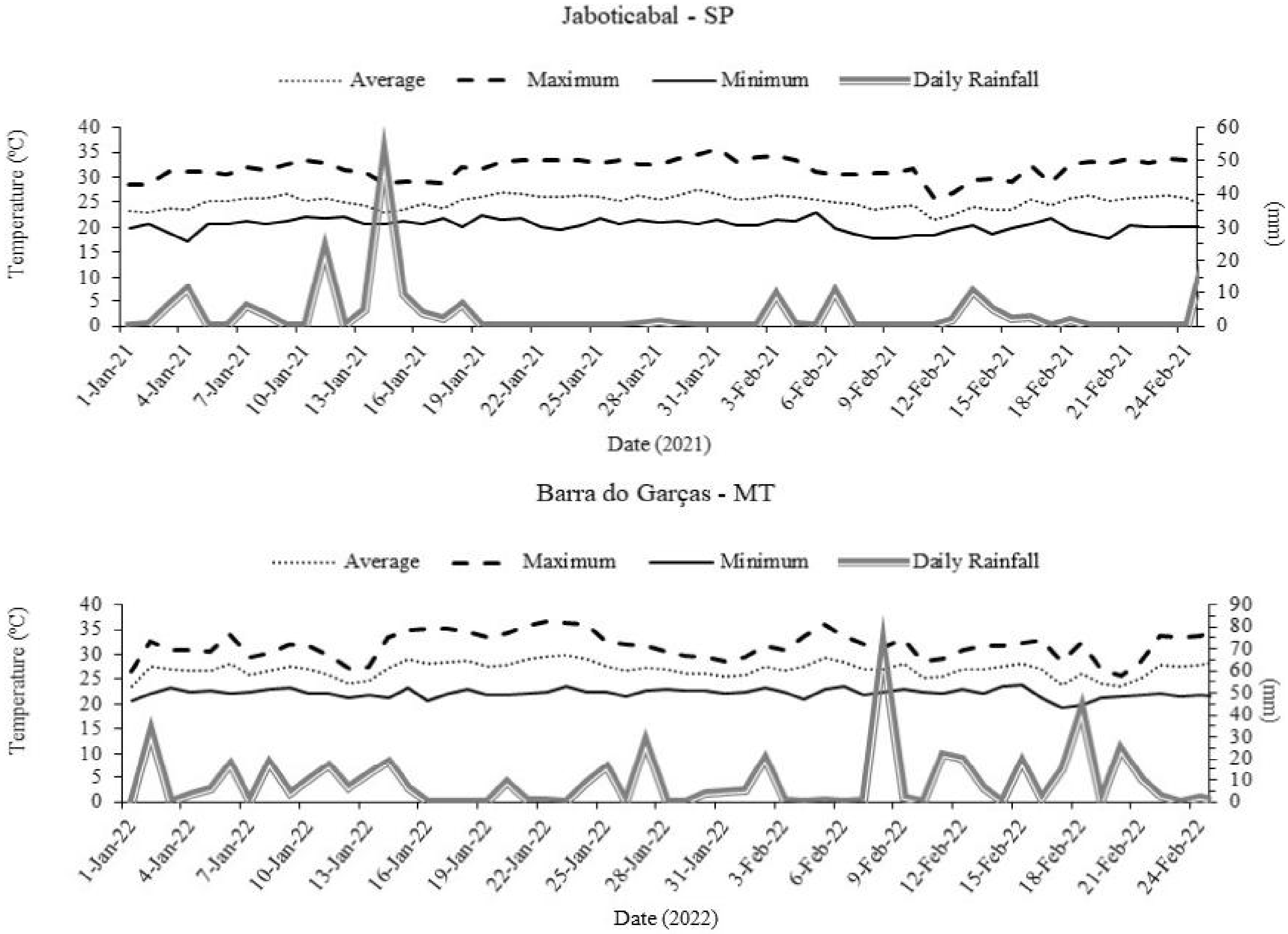
The seeds were purchased from the JS Sementes company in Uberlândia MG. Five samples from different stages of seed processing were chosen to obtain seeds of different specific weights. The seeds were sampled by collecting composite samples called: “Raw Seeds”, “Clean Seeds”, “Clod”, “Straw”, and “Intermediate Table I”, obtained from different discharge spouts of the air and sieve machines, gravitational tables and seed treatment machine, which allowed separation by specific weight (Brasil, 2009; Melo *et al*., 2016).

The samples were received at the Seed Analysis Laboratory of the Plant Production Department of the Faculty of Agricultural and Veterinary Sciences (UNESP), Jaboticabal Campus SP, where they were cleaned using a General Seed Blower® pneumatic blower, set to a specific opening for the species to remove any empty spikelets and plant debris. The “Clod” and “Intermediate Table I” samples were also cleaned manually to separate soil fragments.

The 1000-seed weight was determined by weighing eight subsamples of 100 seeds on a scale with a precision of 0.001 g, with the results expressed in grams (Brasil, 2009) (Table 3). to choose the samples that characterized the seeds of different specific weights.

Preliminary germination tests were carried out with four subsamples of 100 seeds, sown on two sheets of filter paper moistened twice the weight of the paper with distilled water and KNO_3 (0.2%) in transparent acrylic boxes (11.0 x 11.0 x 3.5 cm), at an alternating temperature of 15-35 ºC and an eight-hour light period (Brasil, 2009), with no initial seed dormancy checked

Figure 1 - Minimum, maximum, and average temperatures and daily rainfall observed in the regions of Jaboticabal, SP and Barra do Garças, MT during the experimental period



at the time of the preliminary test. In this way, it was possible to obtain the germination percentage, which was used to calculate the number of seeds from each lot needed for at least 50 seedlings to emerge in the field experiments.

The experimental plots were 1.0 m wide by 5.0 m long, with a standardized useful area in the center of the plots, 25 cm apart at each end. A distance of 10 cm was established between the sowing furrows of different depths. Each experimental plot consisted of a specific weight of seeds, randomized in the experimental units before sowing.

Sowing was conducted by hand in damp soil, and the sowing depths were obtained using a wooden frame, 20 cm wide and 2 cm thick, with the exact measurements for each depth (Figure 2). This ensured that the sowing depth was uniform throughout the furrow. Sowing followed the same pattern of depths, from the lowest to the highest, to better visualize and evaluate the plants in the field.

Irrigations were conducted manually four times a week, with an average distribution to obtain approximately 10 mm of water/m^2 at each irrigation, considering the average accumulated rainfall.

The number of emerged seedlings was counted daily until there was no variation between evaluations for at least five consecutive days, corresponding to 23 days after emergence. The seedling was counted when it emerged, and the coleoptile was fully exposed.

Table 1 - Chemical and particle size analysis of the soil in Jaboticabal SP, 2021

pH $CaCl^2$	O.M.	P_{resin}	K	Ca	Mg	H + Al	S	CEC	BS
(0.01 mol L^{-1})	g dm^{-3}	mg dm^{-3}	------------------------- $mmol_c$ dm^{-3} -------------------------						%
5.0	15.0	20.0	2.1	17.0	5.0	22.0	0.1	46.6	53

Particle size distribution (g kg^{-1})

Clay	Silt	Coarse Sand	Fine sand	Total sand
250	40	300	410	710

Textural class: Sandy Clay Loam

O.M. – Organic matter. CEC – Cation Exchange Capacity. BS – Base saturation

Table 2 - Chemical and particle size analysis of the soil in Barra do Garças - MT, 2022

pH $CaCl_2$	O.M.	Presin	K	Ca	Mg	H + Al	S	CEC	BS
(0.01 mol L^{-1})	g dm^{-3}	mg dm^{-3}	------------------------- $mmol_c$ dm^{-3} -------------------------						%
4.0	22.9	3.8	1.0	6.6	4.2	40.0	--	27.1	23.5

Particle size distribution (g kg^{-1})

Clay	Silt	Coarse Sand	Fine sand	Total sand
350	75	200	375	575

Textural class: Sandy Clay

O.M. – Organic matter. CEC – Cation Exchange Capacity. BS – Base saturation

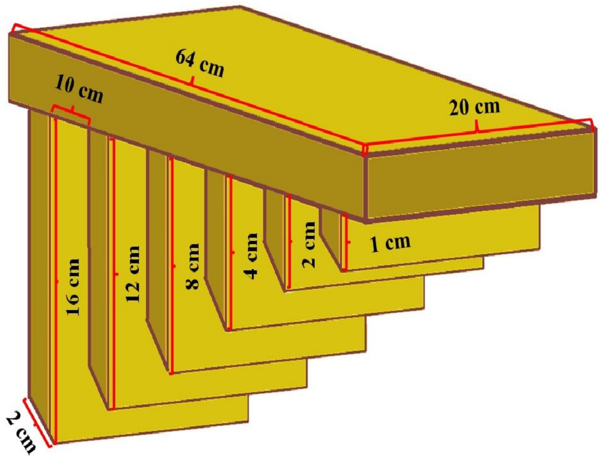
Table 3 - 1000-seed weight of seed samples with different specific weights

Species	Specific weight		
	Low	Medium	High
		(g)	
U. brizantha (cultivar Marandú)	8.61	9.38	10.74

The effects of the treatments were calculated to obtain the percentage of emergence (%E), emergence speed index (ESI), mean emergence time (MET), synchrony (Z), and relative frequency (Rf) of seedling emergence. The equation established by Labouriau and Valadares (1976) was used to calculate the percentage of emergence: %E = (N*100)/A, where %E = seedling emergence percentage, N = total number of seedlings emerged, and A = total number of seeds placed to germinate. The emergence speed index (ESI) of the species studied was calculated using the formula described by Maguire (1962), and the mean emergence time (MET), synchrony (Z), and relative frequency of emergence (Rf) were obtained using the formulas described by Santana and Ranal (2004).

Variations in the relative frequency of emergence of Marandu palisadegrass seedlings were assessed by observing the unimodality or polymodality of the graphical polygons obtained as a function of the different seed depths in the soil over time.

Figure 2 - Schematic of the equipment for drilling into the soil at different depths



The data on %E, ESI, MET, and Z of seedlings were tested for normality and homoscedasticity of variance using the Shapiro-Wilk test and submitted to analysis of variance and F test. The means of the treatments were compared using the Tukey test at 5% probability. Only in cases where there was no interaction between the factors and significant contrasts between the specific seed weight factor were the data adjusted to regression models using the Origin 8.5.1 SR1 program. The regression model was chosen based on the highest coefficient of determination (R^2) value at $p \leq 0.05$ according to the F test, respecting the biological response.

RESULTS AND DISCUSSION

Specific seed weight and sowing depth, evaluated alone or their interaction, influenced all the variables related to the emergence of Marandu palisadegrass seedlings in both years of the experiments (Table 4).

Marandu palisadegrass seedlings emerged at up to 12 cm sowing depth, and no emergence was recorded at 16 cm, regardless of the specific seed weights assessed and the years of study. When evaluating seeds with low specific weight, it can be seen that seedling emergence was higher when they were placed at a depth of 1.0 and 2.0 cm, with values of 86.5 and 78.5%, respectively, compared to the other depths for the 2021 experiment and 84.50 and 81.50% for the 2022 experiment (Table 5).

In 2021, the emergence of seedlings from seeds with a medium-specific weight showed significant contrasts between the sowing depths since the highest values were found when the seeds were sown between 1.0 and 4.0 cm in the soil profile. However, in the experiment conducted in 2022, sowings deeper than 1.0 cm led to reductions in the emergence of Marandu palisadegrass seedlings (Table 5).

Table 4 - Analysis of variance of the variables percentage seedling emergence in the field (%E), emergence speed index (ESI), mean emergence time (AVT), and emergence synchrony (Z) of Marandu palisadegrass seedlings according to the different specific seed weights, sown at different depths, in 2021 and 2022

2021				
Factor of Variation	Variables			
	%E	ESI	MET	Z
$F_{\text{SPECIFIC WEIGHT}}$ (SW)	43.58**	166.62**	133.21**	54.38**
F_{DEPTH} (D)	352.98**	415.20**	948.61**	48.19**
F (SW) x (D)	4.14**	12.11**	7.98**	5.42**
F_{BLOCKS}	0.40^{ns}	0.57^{ns}	1.23^{ns}	1.01^{ns}
C. V. (%)	12.04	11.99	5.79	24.64

Continuation Table 4

2022				
Factor of Variation	Variables			
	%E	ESI	MET	Z
$F_{\text{SPECIFIC WEIGHT}}$ (SW)	50.75**	119.27**	142.01**	113.62**
F_{DEPTH} (D)	334.26**	440.20**	1739.84**	127.86**
F (SW) x (D)	8.21**	15.34**	24.06**	34.50**
F_{BLOCKS}	1.56^{ns}	2.50^{ns}	2.79*	1.23^{ns}
C. V. (%)	13.62	13.19	4.33	16.48

* significant at 5% probability level; ** significant at 1% probability level; ^{ns} not significant

Table 5 - Emergence (%) of Marandu palisadegrass seedlings according to the specific seed weight and sowing depth in 2021 and 2022

2021					
Sowing depth (cm)	Specific weight			$F_{\text{SPECIFIC WEIGHT}}$ (SW)	m.s.d. (SW)
	L	M	H		
1.0	86.5 aB	86.5 aB	99.5 aA	4.51*	12.06
2.0	78.5 aB	88.5 aB	100.0 aA	9.27**	
4.0	63.0 Bb	83.0 aB	99.5 aA	14.34**	
8.0	53.5 bB	50.5 bB	86.5 aA	31.95**	
12.0	20.0 cAB	19.0 cB	32.0 bA	4.19*	
16.0	0.0 dA	0.0 dA	0.0 cA	-	
F_{DEPTH} (D)	97.11**	115.92**	148.22**	-	-
m.s.d. (D)	14.79	-	-		
Sowing depth (cm)	Specific weight 2022			$F_{\text{SPECIFIC WEIGHT}}$ (SW)	m.s.d.(SW)
	B	M	A		
1.0	84.5 aB	85.0 aB	98.0 aA	1.11^{ns}	11.93
2.0	81.5 aB	72.5 bB	94.5 aA	9.89**	
4.0	57.5 bB	53.0 cB	90.0 aA	33.33**	
8.0	38.5 cB	25.0 dC	89.5 aA	46.80**	
12.0	18.0 dA	16.5 dA	22.0 bA	0.63^{ns}	
16.0	0.0 eA	0.0 eA	0.0 cA	-	
F_{DEPTH} (D)	108.34**	100.57**	141.76**	-	-
m.s.d. (D)	14.64	-	-		

* significant at 5% probability level; ** significant at 1% probability level; ^{ns} not significant. Means followed by the same uppercase letter in the line and lowercase letter in the column do not differ statistically by the Tukey test ($p < 0.05$). (L = low specific weight; M = medium specific weight; H = high specific weight)

Deeper sowings can show discrepancies of up to 8 ºC less than in more superficial positions in the soil profile. Lower temperatures can delay the seed soaking process and consequently affect the emergence time, as Carvalho and Nakagawa (2012) and Marques *et al*. (2022) observe.

As a result, it is important to note that the development of some weed species can be compromised by soil preparation processes that promote the incorporation of seeds at greater depths (Marques *et al*., 2019). This leads to an increase in the mechanical resistance imposed by the soil, as well as a reduction in temperature, O_2 availability, and an increase in CO_2 accumulation, forming fermented compounds during the respiratory process (Taiz; Zeiger, 2013), which can affect the germination process (Zuffo *et al*., 2014), which would explain the results found here for Marandu palisadegrass.

Seedlings of *Urochloa decumbens* (Stapf) R. D. Webster (brachiaria grass) and *Cenchrus echinatus* L. (southern sandbur) were able to emerge when sown between 0.5 and 12.0 cm deep. The researchers added that when sowings were made between 2.0 and 4.0 cm deep, there was an increase in the emergence of *U. decumbens* and *C. echinatus* seedlings. However, sowings at a depth of 12 cm led to significant reductions in the emergence of both species, corroborating the results observed in this research for Marandu palisadegrass (Marques *et al*., 2022).

In both years, seeds with a high specific weight sown between 1.0 and 8.0 cm deep had the highest seedling emergence rates, higher than those sown at 12.0 cm in the soil profile. When analyzing the specific seed weight factor in isolation, it can be seen that, regardless of the year the experiment was conducted and the sowing depth, seeds with a high specific weight resulted in higher average emergence rates for Marandu palisadegrass seedlings, with values of over 86.5% (Table 5).

Germination potential and vigor are influenced by the chemical composition of the seed, especially the deposition of reserve constituents, which can be affected by the position of the seed within the inflorescence. The association between the start of flowering, the pollination, and the climatic conditions prevailing during flower ripening directly impacts the process uniformity and the seed's chemical composition (Ribeiro *et al*., 2019).

The seeds with the largest size or highest specific weight have been best nourished during development. This fact becomes more evident in plants where the seeds do not form at the same time, as in the case of grasses in general, where the last to form at the ends of the ears, spikelets, or panicles are usually smaller or of lower specific weight, and may undergo a late natural degrading process. Normally, seeds with a higher specific weight have well-formed embryos with greater reserves and are potentially the most vigorous (Carvalho; Nakagawa, 2012).

It can, therefore, be inferred that seedlings from Marandu palisadegrass seeds with higher specific weights can establish greater competitive pressure with the crops of interest since there was significant emergence up to a depth of 8.0 cm. As a result, mechanical soil preparation operations to suppress the spread of weeds in the field, which may not be efficient at turning over the soil and incorporating plant remains at depths greater than this, become unfeasible. Nagahama *et al*. (2014) add that surface tillage can lead to greater infestation of areas by weeds. This indicates that areas subjected to mechanical tillage may need additional control before the crop is sown to avoid high infestation by weed seeds capable of germinating at greater depths.

Sowings between 1.0 and 4.0 cm deep promoted the highest values, did not affect the ESI of the Marandu palisadegrass seedlings, and showed no dependency relationship with the specific weights of the seeds evaluated and the year in which the experiment was conducted. It is important to note that, when evaluating the specific weight factor in isolation, it can be seen that seeds with a high specific weight had the highest ESI values when sown between 1.0 and 8.0 cm deep in the years 2021 and 2022 (Table 6).

The decrease in the emergence speed index as a result of the increase in sowing depth observed in this study may have occurred due to the quantities of reserve material in the seeds being insufficient to break through the soil's natural barrier (Santos *et al*., 2015; Souza *et al*., 2011). In addition, the process of secondary or induced dormancy, which refers to the state of dormancy induction under environmental conditions that are not favorable to germination (Chen *et al*., 2020), such as the absence of light, may also have directly influenced the reduction in the emergence of Marandu palisadegrass seedlings at greater depths (Marques *et al*., 2022).

Placing the seeds between 1.0 and 4.0 cm deep gave the lowest mean emergence time for the Marandu palisadegrass seedlings, in contrast to the other depths. Sowing at a depth of 12 cm resulted in a greater increase in time in days for seedlings of this species to emerge, regardless of the specific seed weights evaluated and the year the experiments were conducted (Table 7). These results show greater efficiency in the emergence of seedlings of this species in shallower sowings in the soil profile (1.0 to 4.0 cm), regardless of the specific weight evaluated. Marques *et al*. (2023) point out that higher temperatures are observed at these depths compared to sowing depths greater than 4.0 cm (8.0 and 12.0 cm). Lower temperatures can delay the soaking process of the seeds and consequently affect the time to emergence.

When evaluating the specific seed weight factor as a function of sowing depth, significant contrasts were found between low, medium, and high specific seed weights for the mean emergence time of Marandu palisadegrass seedlings, regardless of the sowing depth evaluated and in both years. The greatest time requirements for seedlings of this species to emerge were found when low and medium-specific weight seeds were used (Table 7).

It can be seen that sowing depths of up to 12 cm did not influence the emergence synchrony of Marandu palisadegrass seedlings, even when seeds with different specific weights were sown in different years. Notably, seeds with a high specific weight, positioned at 1.0, 2.0, 4.0, and 8.0 cm deep, showed the highest emergence synchrony values compared to seeds with a low and medium-specific weight in the experiments conducted in 2021 and 2022 (Table 8).

Table 6 - Emergence speed index (ESI) of Marandu palisadegrass seedlings according to the specific seed weight and sowing depth in 2021 and 2022

2021					
Sowing depth (cm)	Specific weight			$F_{SPECIFIC\ WEIGHT}$ (SW)	m.s.d. (SW)
	L	M	H		
1.0	7.77 aB	7.33 aB	11.38 aA	47.12**	1.10
2.0	7.01 aB	7.56 aB	11.34 aA	53.13**	
4.0	6.50 aB	6.57 aB	11.01 aA	63.84**	
8.0	3.99 bB	3.64 bB	8.13 bA	59.61**	
12.0	1.36 cAB	1.22 cB	2.33 cA	3.48*	
16.0	0.00 dA	0.00 cA	0.00 dA	-	
F_{DEPTH} (D)	98.05**	101.83**	239.55**	-	-
m.s.d. (D)	1.35	-	-		

2022					
Sowing depth (cm)	Specific weight			$F_{SPECIFIC\ WEIGHT}$ (SW)	m.s.d. (SW)
	B	M	A		
1.0	7.76 aB	7.52 aB	9.93 aA	13.83**	1.01
2.0	7.46 aB	7.53 aB	9.94 aA	35.53**	
4.0	6.69 aB	6.87 aB	8.89 aA	90.67**	
8.0	2.35 bB	1.75 bB	5.83 bA	55.61**	
12.0	1.10 cA	1.09 bcA	1.38 cA	0.31^{ns}	
16.0	0.00 cA	0.00 cA	0.00 dA	-	
F_{DEPTH} (D)	121.71**	127.52**	221.65**	-	-
m.s.d. (D)	1.23	-	-		

* significant at 5% probability level; ** significant at 1% probability level; ^{ns} not significant. Means followed by the same uppercase letter in the line and lowercase letter in the column do not differ statistically by the Tukey test ($p < 0.05$). (L = low specific weight; M = medium specific weight; H = high specific weight)

Table 7 - Mean emergence time (MET, days) of Marandu palisadegrass seedlings according to the specific seed weight and

2021					
Sowing depth (cm)	Specific weight			$F_{SPECIFIC\ WEIGHT}$ (SW)	m.s.d. (SW)
	L	M	H		
1.0	6 cA	6 cA	4 cB	37.77**	0.50
2.0	6 cA	6 cA	4 cB	37.07**	
4.0	6 cA	6 bcA	5 cC	47.16**	
8.0	7 bA	7 bA	5 bB	44.01**	
12.0	8 aA	8 aA	7 aB	7.08**	
16.0	0 dA	0 dA	0 dA	-	
F_{DEPTH} (D)	377.71**	373.36**	253.50**	-	-
m.s.d. (D)		0.61		-	-

Continuation Table 7

2022					
Sowing depth (cm)	L	M	H	$F_{SPECIFIC\ WEIGHT}$ (SW)	m.s.d. (SW)
	Specific weight				
1.0	6 bA	6 cA	5 cB	21.97**	0.41
2.0	6 bA	6 cA	5 cB	29.39**	
4.0	6 bA	6 cA	5 cB	123.25**	
8.0	8 aA	7 bB	6 bC	80.79**	
12.0	8 aA	8 aB	8 aA	6.91**	
16.0	0 dA	0 cA	0 dA	-	
F_{DEPTH} (D)	691.50**	577.85**	518.61**	-	-
m.s.d. (D)		0.50		-	-

* significant at 5% probability level; ** significant at 1% probability level; ^{ns} not significant. Means followed by the same uppercase letter in the line and lowercase letter in the column do not differ statistically by the Tukey test ($p < 0.05$). (L = low specific weight; M = medium specific weight; H = high specific weight)

Table 8 - Emergence synchrony (Z) of Marandu palisadegrass seedlings according to the specific seed weight and sowing depth in 2021 and 2022

2021					
Sowing depth (cm)	Specific weight			$F_{SPECIFIC\ WEIGHT}$ (SW)	m.s.d. (SW)
	L	M	H		
1.0	0.31 aB	0.21 aB	0.49 aA	17.97**	0.11
2.0	0.31 aB	0.21 aB	0.49 aA	18.01**	
4.0	0.35 aB	0.22 aC	0.47 aA	14.07**	
8.0	0.25 aB	0.21 aB	0.56 aA	30.97**	
12.0	0.27 aA	0.30 aA	0.32 bA	0.47^{ns}	
16.0	0.00 bA	0.00 bA	0.00 cA	-	
F_{DEPTH} (D)	13.89**	8.47**	36.67**	-	-
m.s.d. (D)		0.14		-	-
2022					
Sowing depth (cm)	Specific weight			$F_{SPECIFIC\ WEIGHT}$ (SW)	m.s.d. (SW)
	L	M	H		
1.0	0.33 aB	0.25 aC	0.52 aA	84.37**	0.07
2.0	0.22 aB	0.23 aB	0.48 aA	85.35**	
4.0	0.24 aB	0.28 aB	0.41 aA	90.58**	
8.0	0.21 aB	0.23 aB	0.40 aA	6.23**	
12.0	0.28 aA	0.17 aB	0.17 bB	19.60**	
16.0	0.00 bA	0.00 bA	0.00 cA	-	
F_{DEPTH} (D)	31.71**	31.29**	133.86**	-	-
m.s.d. (D)		0.12		-	-

* significant at 5% probability level; ** significant at 1% probability level; ^{ns} not significant. Means followed by the same uppercase letter in the line and lowercase letter in the column do not differ statistically by the Tukey test ($p < 0.05$). (L = low specific weight; M = medium specific weight; H = high specific weight)

Higher emergence synchrony values may express the physiological homogeneity of the seeds at the time of germination. The synchrony of emergence establishes how species that colonize the same physical space can exploit different opportunities, distributing their germination differentially over time, considering that the germination process is not perfectly synchronized (Oliveira; Silva; Alves, 2017).

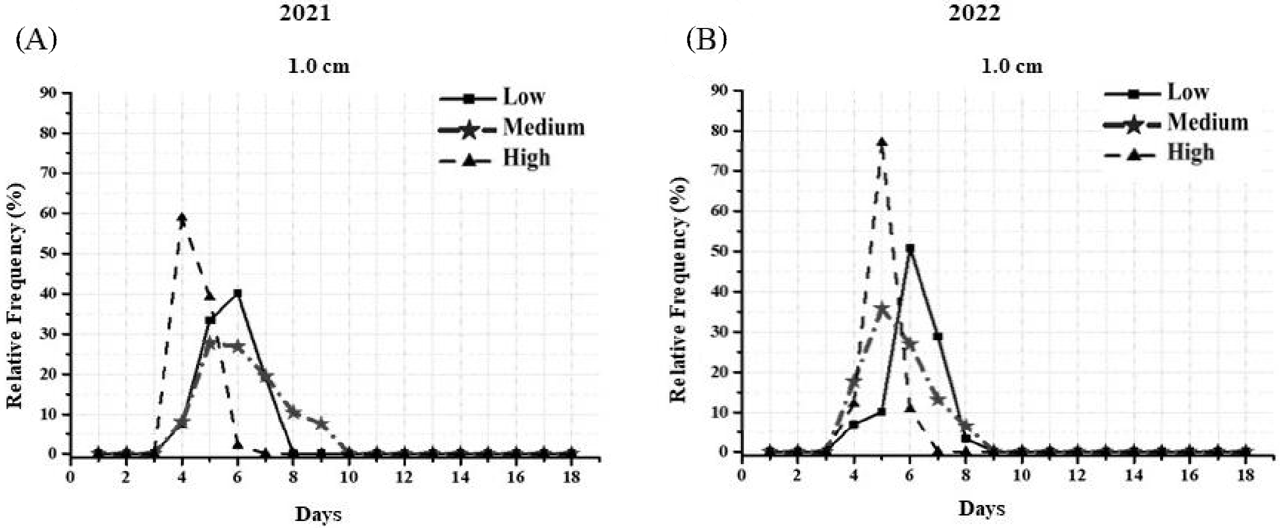
When analyzing the relative frequency of emergence of Marandu palisadegrass seedlings, it can be seen that the greatest uniformity was obtained when the seeds with low, medium, and high specific weights were placed at a depth of 1.0 cm. The polygons of the relative emergence frequency distribution for this depth tended towards unimodality, with emergence peaks between the third and ninth day after sowing for the experiment conducted in 2021 and between the third and eighth day when evaluated in 2022 (Figure 3A and B). The greatest uniformity of emergence of sword grass (*Paspalum virgatum* L.) occurred when the seeds were located on the surface and 1.0 cm deep, corroborating the results found in this study (Marques *et al*., 2019).

The relative frequency polygons for the 2.0 and 4.0 cm sowing depths tended towards unimodality only when seeds with a high specific weight were sown, with emergence peaks between the third and sixth day after sowing, regardless of the year in which the experiment was conducted (Figure 3C, D, E, and F). When Marandu palisadegrass seeds with low and medium-specific weights were placed at 2.0 and 4.0 cm and, regardless of the specific weight of the seeds, at 8.0 and 12.0 cm depth, there was polymodality in the relative emergence frequency polygons, characterized by several emergence peaks, indicating less homogeneity in the emergence behavior of the seeds in both years of the experiments (Figure 3C, D, E, F, G, H, I and J).

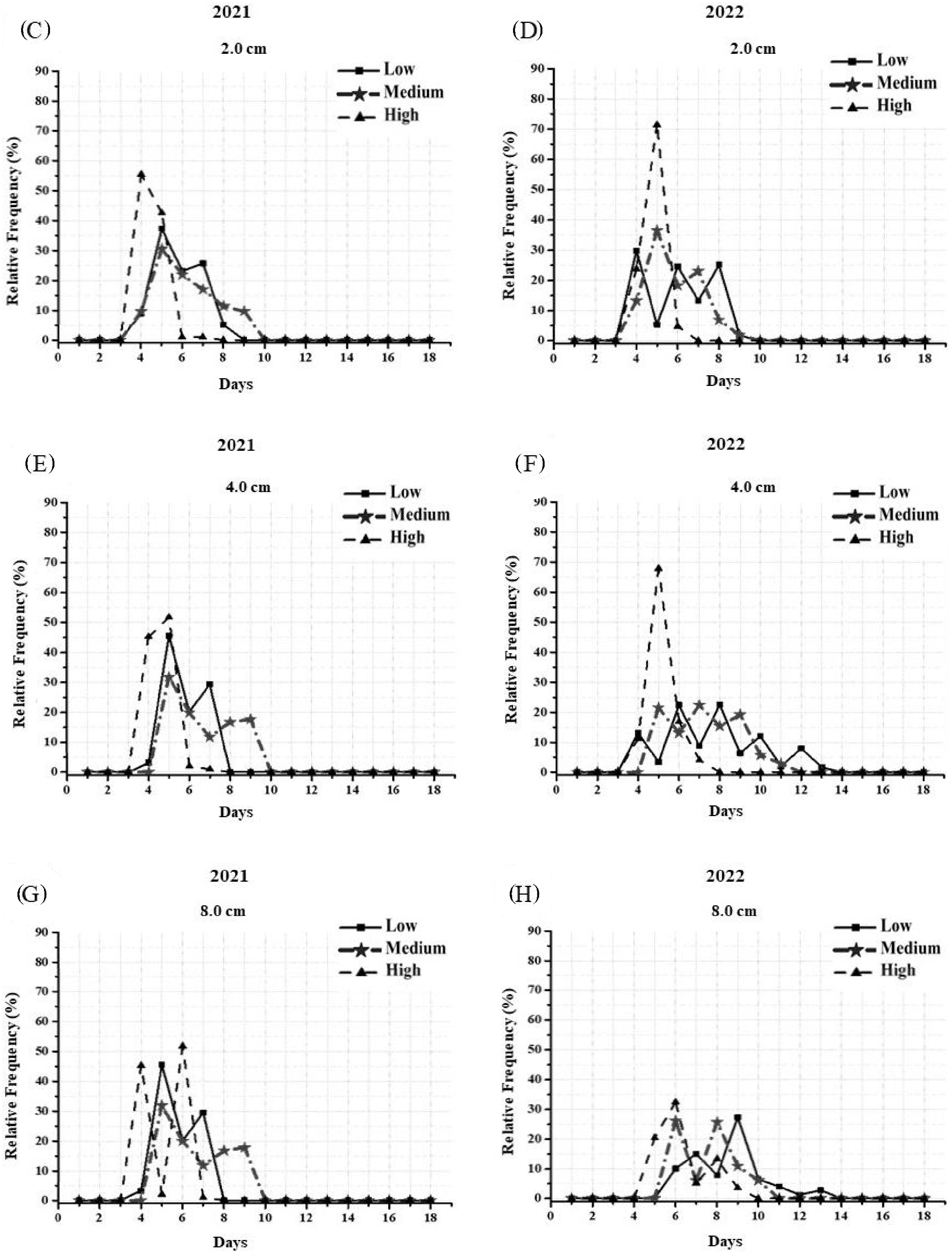
Weeds have developed strategies during the evolutionary process that facilitate the species' establishment and survival in the environment (Concenço *et al.*, 2014). From a reproductive point of view and in general, weeds produce a high quantity of viable seeds, with morphology that facilitates dispersal and with physiological devices intrinsic to dormancy, thus ensuring staggered seed germination (Sadeghloo; Asghari; Ghaderi Far, 2013). This fact helps to understand the emergence behavior of Marandu palisadegrass seedlings observed in this study regarding the amplitude of the period in which seedling emergence frequencies were observed at greater depths.

The relative frequency peaks are related to the synchronization of emergence, i.e., the greater the number of peaks, the greater the number of times any seeds germinated and emerged (Jeromini *et al*., 2020). It is therefore assumed that soil preparation using moldboard plows, for example, can be beneficial in reducing the speed of emergence and, consequently, the intensity of proliferation of Marandu palisadegrass as a weed due to the deposition of seeds at depths greater than 35 cm after mechanical operations (Rigon *et al*., 2020).

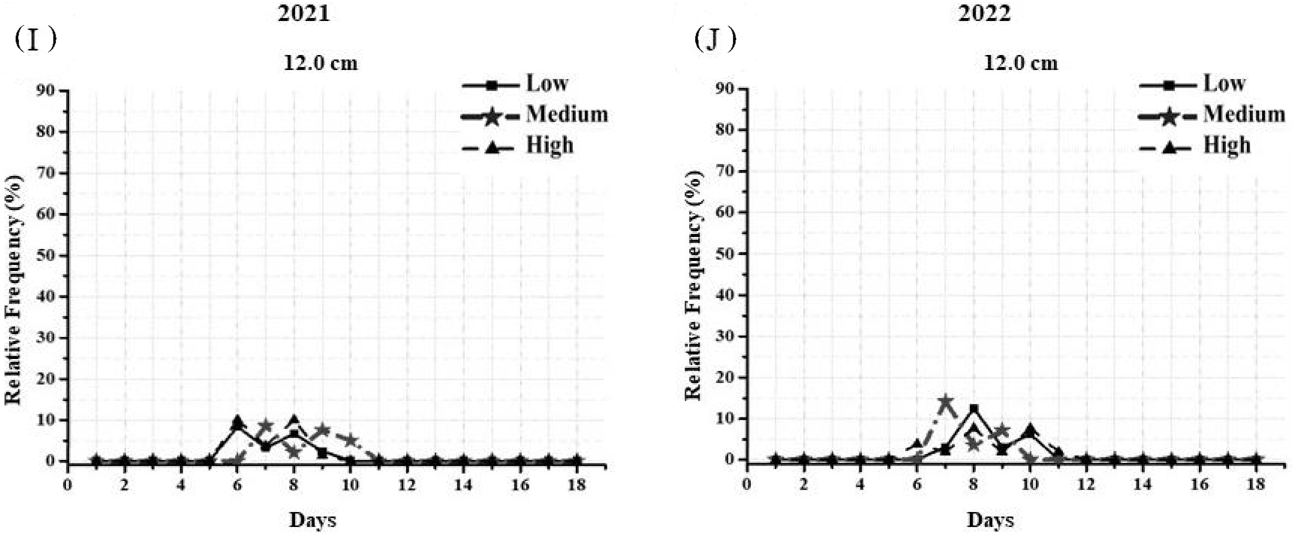
Figure 3 - Relative frequency of emergence (Rf) of Marandu palisadegrass seedlings after depositing seeds with different specific weights at different sowing depths (2021 = Figures A, C, E, G, and I 1.0, 2.0, 4.0, 8.0, and 12.0 cm, respectively) and (2022 = Figures B, D, F, H, and J 1.0, 2.0, 4.0, 8.0, and 12.0 cm, respectively)



Continuation Figure 3



Continuation Figure 3



CONCLUSIONS

1. Marandu palisadegrass seedlings emerged at depths of up to 12 cm, regardless of the specific weight of the seeds;
2. Sowing between 1.0 and 4.0 cm deep promoted the lowest mean emergence time and the highest emergence speed index and percentage of seedling emergence in the field, regardless of the specific weight of the seeds;
3. Seeds with a high specific weight resulted in the highest percentages of emergence, speed index, and synchrony of emergence of Marandu palisadegrass seedlings in the field;
4. Depths greater than 1.0 cm lead to the staggering of the seedling emergence process in the field.

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