مجلة جامعة سبها للعلوم البحتة والتطبيقية
Sebha University Journal of Pure & Applied Sciences

Journal homepage: www.sebhau.edu.ly/journal/jopas

An Investigation of the Effects of Seed Depth and Rainfall Rates on the Characteristics of Brome (Bromus rigidus Roth)

Muoftah Bataw

Department of Natural Resources, Faculty of Natural Resources and Environmental Sciences, Omar Almukhtar University, Al Bayda, Libya.

Keywords:
Bromus Rigidus Roth.
Rates of Rain.
Depth of Seed.
Interaction.
Brome Weeds.
Al Jabal Al Akhdar Libya.

A B S T R A C T

This study was conducted over six months during the wheat-growing season in the Green Mountain region of Libya, an area characterized by varying rainfall levels. A factorial design was employed to examine the effects of seed burial depth and rainfall levels on the growth and productivity of Bromus rigidus Roth. Seeds were sown at depths of 0 cm, 1 cm, 5 cm, and 10 cm under three rainfall levels (250 mm, 350 mm, and 500 mm per year). Results indicated that seeds buried at a depth of 5 cm achieved the highest productivity in terms of dry weight and seed yield, while no germination occurred at a depth of 10 cm, likely due to oxygen deficiency. Rainfall levels significantly influenced plant growth, with the highest productivity recorded at 500 mm per year. The interaction between seed depth and rainfall level revealed that a depth of 5 cm combined with 500 mm per year of rainfall was optimal for achieving superior germination, growth, and seed production. These findings provide insights into the ecological adaptability of Bromus rigidus and its management in arid and semi-arid regions.

دراسة تأثير عمق البذور ومعدلات الامطار على خصائص الانتاج لحشيشة البروموس Bromus Rigidus Roth

مفتاح بطاو

قسم الموارد الطبيعية ، كلية الموارد الطبيعية وعلوم البيئة، جامعة عمر المختار، البيضاء، ليبيا.

الكلمات المفتاحية:
أعشاب البروموس.
معدلات الأمطار.
عمق البذور.
التداخل.
أعشاب بروم.
الجبل الأخضر ليبيا.

الملخص

تم إجراء هذه الدراسة على مدار ستة أشهر خلال موسم زراعة القمح في منطقة الجبل الأخضر بليبيا، وهي منطقة تتميز بتفاوت معدلات الأمطار. استُخدم تصميم عاملي لدراسة تأثير عمق البذور ومعدلات الأمطار على نمو وإنتاجية نبات Bromus rigidus Roth. تمت زراعة البذور على أعماق مختلفة (0 سم، 1 سم، 5 سم، 10 سم) تحت ثلاث معدلات هطول الأمطار (250 ملم، 350 ملم، و500 ملم/السنة). أظهرت النتائج أن البذور المزروعة على عمق 5 سم حققت أعلى إنتاجية. على النقيض، لم يحدث أي إنبات عند عمق 10 سم بسبب نقص الأكسجين. كان لمعدلات الأمطار تأثير كبير على نمو النبات، حيث تم تسجيل أعلى إنتاجية عند معدل 500 ملم/السنة. كما أوضحت التداخلات بين عمق البذور ومعدلات الأمطار أن العمق 5 سم مع معدل 500 ملم/السنة كان الأمثل لتحقيق أفضل معدلات الإنبات والنمو وإنتاج البذور. توفر هذه النتائج رؤى حول قدرة Bromus rigidus على التكيف بيئيًا وإدارته في البيئات الجافة وشبه الجافة.

1. Introduction

Bromus rigidus Roth, commonly known as rigid brome, is a grass species native to the Mediterranean region that has adapted to thrive in diverse and challenging environments, including arid and semi-arid agricultural ecosystems [1]. Its resilience and ability to establish in resource-limited conditions make it an intriguing subject for research, particularly in the context of climate variability and its impact on plant growth. While *Bromus rigidus* has often been viewed as a competitive species in certain agricultural systems, its growth patterns and adaptability offer valuable insights into strategies for sustainable land

*Corresponding author.
E-mail addresses: mbataw@hotmail.co.uk.

Article History : Received 29 April 24 - Received in revised form 30 January 25 - Accepted 06 April 25

management and improved agricultural productivity in marginal lands [2].

The physiological and ecological characteristics of *Bromus rigidus*, such as its response to seed burial depth and moisture availability, position it as a model species for understanding plant behavior in water-limited environments. Previous research has shown that the depth at which seeds are buried plays a crucial role in germination and seedling emergence. Shallow planting depths are associated with higher germination rates due to greater exposure to light and temperature cues [3], while deeper planting can suppress emergence because of limited oxygen availability and increased physical resistance [4]. Additionally, moisture availability is a critical factor influencing seedling establishment, especially in regions with variable rainfall. Water stress has been shown to impede the emergence and growth of many plant species [5].

Studies on other species, such as *Convolvulus arvensis* [6] and *Crotalaria* [7], have demonstrated how seed depth and moisture interact to influence germination and early growth. However, these findings cannot be directly applied to *Bromus rigidus* due to species-specific physiological and ecological differences. Furthermore, most existing research on *Bromus rigidus* has focused on its competitive behavior in crop production systems, often framing it as a weed to be managed [8, 2]. This perspective overlooks the potential benefits of understanding its growth dynamics for applications in sustainable agriculture, such as improving soil stability, enhancing biodiversity, and optimizing cropping systems for water-limited conditions [9].

Current research on *Bromus rigidus* has extensively examined the effects of seed burial depth on seed viability and germination. For instance, studies have shown that both surface-sown and buried seeds of *B. rigidus* deplete within 15 months, with germination rates varying based on depth [10]. However, the combined effects of seed burial depth and rainfall on the germination and establishment of *B. rigidus* remain underexplored. While research on related species, such as *Lolium rigidum* (rigid ryegrass), has investigated the interaction between seed burial depth and environmental factors like rainfall [11], there is a notable gap in the literature specifically addressing how these factors interact to influence *B. rigidus* populations. Exploring these factors together is particularly important in the context of climate change, where precipitation patterns are becoming increasingly erratic [12, 13].

2. Aims and Objectives

2.1. This research primarily aims to investigate how environmental factors, specifically seed burial depth and rainfall, influence the germination, seedling emergence, and growth of *Bromus rigidus*. The specific objectives of this study are as follows:

- To determine how varying seed burial depths affect the germination rates and seedling emergence of *Bromus rigidus*.
- To assess how different rainfall levels affect seedling growth, biomass accumulation, and seed production in *Bromus rigidus*.
- To explore the interaction between seed depth and rainfall on the overall productivity and competitive ability of *Bromus rigidus* in agricultural fields.

2.2. By achieving these objectives, this research seeks to enhance understanding of how *Bromus rigidus* responds to environmental factors, providing valuable insights for developing effective weed management strategies in agricultural systems.

3. Methods

3.1. Study Sites

research was conducted at three distinct locations in the Al Jabal Al Akhdar (Green Mountain) region of Libya, chosen to represent varying rainfall rates and environmental conditions. These sites offered a diverse ecological backdrop for evaluating the germination and productivity of *Bromus rigidus*. Rainfall data for the region were based on meteorological records obtained from local weather stations and reports.

3.2. Experimental Design

A factorial experiment was designed to investigate the effects of seed depth and simulated rainfall on the germination and productivity of *Bromus rigidus*. The experiment incorporated two main factors:

- Factor 1: Seed Depth – Seeds were sown at four depths: 0 cm (on the soil surface), 1 cm, 5 cm, and 10 cm.
- Factor 2: Rainfall Amount – Three rainfall scenarios (250 mm, 350 mm, and 500 mm/year) were estimated based on regional weather patterns and historical data.

The experiment spanned six months, from mid-November to mid-May, aligning with the wheat-growing season in the region. A completely randomized design (CRD) was used, with three replicates per treatment combination at each study site [14].

3.3. Planting and Cultivation

Cubic plastic boxes (30 × 30 × 30 cm) were filled with homogenized natural soil collected from agricultural fields near the study sites. The soil was sieved and homogenized to ensure uniformity and remove large debris. Ten seeds per box were planted at the designated depths (0, 1, 5, or 10 cm). Plants were grown under natural conditions, and the experiment continued until the end of the growing season.

3.4. Data Collection

At the end of the agricultural season in mid-May, plants were harvested, and the following parameters were measured:

- Germination rate – Number of plants that emerged in each box.
- Number of branches per plant – Total branches counted per plant.
- Dry weight per plant – Biomass measured after drying plants at 60°C until a constant weight was reached.
- Number of seeds per plant – Total seeds counted per plant.

Data from all three sites were averaged to enhance robustness and account for site-specific variability [8].

3.4. Statistical Analysis

A two-way analysis of variance (ANOVA) was used to evaluate the effects of seed depth, rainfall levels, and their interaction on all measured traits. Post-hoc comparisons were performed using Tukey's HSD test to identify significant differences among treatment means. Results are presented as mean values, with statistical significance set at $P \leq 0.05$.

3.5. Design and Replication

The experiment used a factorial design within a completely randomized design (CRD) framework. Each treatment combination was replicated three times, and the results from the three study sites were averaged before statistical analysis.

4. Results

Table 1: Effect of Seed Depth on Brome Productivity

Seed Depth (cm)	Dry Weight/Plant (g)	Number of Seeds Produced/Plant	Number of Tillers/ Plant	Germination Percentage (%)
0	3.07 b	3.88 c	1.89 c	88.34 a
1	4.92 b	11.00 b	2.78 b	80.55 a
5	10.11 a	27.66 a	3.56 a	82.77 b
10	0.00 c	0.00 c	0.00 d	0.00 c

Values with similar letters (e.g., "a," "b," "c") for each trait did not differ significantly at a probability level of 0.05

Table 1 shows that seed depth significantly affects brome productivity (**$p < 0.05$**). Seeds planted at 5 cm exhibited the highest dry weight, number of seeds produced, and tillering. Although seeds at 0 cm achieved the highest germination percentage (88.34%) where data is expressed in mean average, this did not translate into superior growth, highlighting the importance of moderate planting depths.

Table 2: Effect of Rainfall Rates on Brome Productivity

Rainfall (mm/year)	Dry Weight/Plant (g)	Number of Seeds Produced/ Plant	Number of Tillers/ Plant	Germination Percentage (%)
250	2.73 b	1.00 c	1.91 b	55.83 b
350	4.16 b	10.66 b	2.25 b	55.00 b
500	7.79 a	21.00 a	2.75 a	66.66 a

Values with similar letters for each trait did not differ significantly at a probability level of 0.05.

Table 2 shows that rainfall significantly influences brome growth and productivity (**$p < 0.05$**). At 500 mm/year, germination, dry weight, and seed production were maximized, while lower rainfall levels (250 and 350 mm/year) resulted in suboptimal growth. The difference in germination percentages between 250 mm and 350 mm was negligible.

Table 3: Interaction Between Seed Depth and Rainfall on Brome Productivity

Seed Depth (cm)	Rainfall (mm)	Dry Weight/ Plant (g)	Number of Seeds Produced/ Plant	Number of Tillers/ Plant	Germination Percentage (%)
0	250	91.66 ab	0.00 c	0.00 e	0.00 c
	350	75.00 cd	2.00 bc	0.00 e	3.36 bc
	500	98.33 a	2.67 ab	8.66 d	4.86 bc
1	250	75.00 cd	2.00 bc	0.00 e	3.46 bc
	350	78.33 bc	2.67 ab	10.66 d	4.06 bc
	500	88.33 a-c	3.67 a	19.34 c	6.23 b
5	250	51.66 e	3.67 a	0.00 e	4.03 bc
	350	61.66 de	3.34 a	28.00 b	8.23 b
	500	75.00 cd	3.67 a	52.00 a	18.06 a
10	250	0.00 h	0.00 c	0.00 e	0.00 c
	350	0.00 h	0.00 c	0.00 e	0.00 c
	500	0.00 h	0.00 c	0.00 e	0.00 c

Values with similar letters for each trait did not differ significantly at a probability level of 0.05.

Table 3 shows that the interaction of seed depth and rainfall significantly influenced brome productivity (**p < 0.05**). Seeds planted at 5 cm depth and exposed to 500 mm/year rainfall exhibited the highest productivity across all traits, with maximum germination (18.06%) and dry weight (75 g). Conversely, no plants germinated at 10 cm depth under any rainfall condition.

Table 4: ANOVA Summary for Seed Depth, Rainfall, and Their Interaction

Trait	Source of Variation	F-Value	Degrees of Freedom (df)	p-Value
Dry Weight/Plant (g)	Seed Depth	180.52	3	0.0001
	Rainfall	38.29	2	0.0002
	Seed Depth × Rainfall	22.48	6	0.002
Number of Seeds/Plant	Seed Depth	90.85	3	0.0003
	Rainfall	27.83	2	0.00025
	Seed Depth × Rainfall	18.65	6	0.0025
Number of Tillers/Plant	Seed Depth	123.89	3	0.00015
	Rainfall	18.65	2	0.003
	Seed Depth × Rainfall	14.92	6	0.0035
Germination Percentage	Seed Depth	136.93	3	0.00012
	Rainfall	14.78	2	0.004
	Seed Depth × Rainfall	12.84	6	0.0045

Table 4 presents significant results (**p < 0.05**) indicate that the tested factor or interaction had a statistically significant influence on the respective trait. Higher F-values correspond tgreater relative contributions of the factor or interaction to variability in the measured trait.

5. Discussion

This study demonstrates the combined effects of seed depth and rainfall on the germination and growth of *Bromus rigidus*. Seeds planted at 5 cm depth consistently exhibited superior productivity, likely due to optimal moisture retention and reduced oxygen limitation. These findings align with previous studies, such as [3], which reported that greater seed depths inhibit germination due to oxygen diffusion constraints and physical barriers to seedling emergence. Similarly, [15] observed a decline in seedling emergence percentage with increasing soil depth, consistent with the trends reported in this study.

Rainfall also played a crucial role, with higher levels (500 mm/year) enhancing germination, biomass, and seed production. This supports the findings of [5], who emphasized the importance of adequate moisture for seedling establishment. Interestingly, the negligible differences in germination between 250 mm and 350 mm rainfall suggest that *Bromus rigidus* tolerates moderate drought conditions but benefits substantially from higher moisture levels.

These findings also have implications for weed management strategies. Although surface-sown seeds exhibited higher germination rates, they produced lower biomass and seed yield compared to those planted at 5 cm depth. [13] reported that shallow planting depths increase predation risk and exposure to environmental stressors, such as desiccation and temperature fluctuations, reducing seedling competitiveness. Conversely, seeds placed at 5 cm depth were optimally positioned to balance moisture retention and oxygen availability, resulting in higher productivity.

In the context of climate change, the ability of *Bromus rigidus* to tolerate moderate drought (250–350 mm rainfall) indicates resilience to fluctuating precipitation patterns commonly observed in arid and semi-arid regions [4]. However, the substantial increase in productivity at 500 mm/year highlights the potential benefits of supplemental irrigation in years of reduced precipitation. These results emphasize the need for adaptive water management strategies to counteract climate variability.

The interaction between seed depth and rainfall highlights the role of soil-water dynamics in optimizing plant growth. Seeds planted at 5 cm under 500 mm rainfall achieved the highest productivity, outperforming all other combinations. Mechanistically, the absence of germination at 10 cm depth across all rainfall levels suggests that excessive moisture retention and oxygen deprivation were key limiting factors, as suggested by [9]. Future studies incorporating soil moisture sensors and oxygen diffusion analysis could provide deeper insights into these processes.

The trends observed in this study are consistent with findings in other cereal-associated weeds, such as *Avena fatua* (wild oats), where intermediate planting depths and adequate rainfall promoted greater biomass and seed production [14]. These similarities suggest that the strategies identified here may be broadly applicable across multiple weed species, particularly in arid ecosystems.

These findings offer practical recommendations for optimizing *Bromus rigidus* productivity in arid and semi-arid regions. Moderate seed depths (5 cm) combined with irrigation equivalent to 500 mm/year rainfall can maximize yield while maintaining soil health. Uniform planting depths across fields could further enhance productivity by reducing growth variability. Additionally, adopting these practices may contribute to improved sustainability in *Bromus rigidus* production systems, reducing reliance on additional agricultural inputs.

6. Future Research Directions

While this study was conducted under controlled conditions, field validation is necessary to confirm the applicability of these findings in natural settings. Expanding this research to other cereal-associated weeds could determine whether these results are species-specific or broadly generalizable. Additionally, long-term studies on the effects of planting depth and rainfall on soil health and nutrient cycling would provide insights into the sustainability of these agricultural practices.

7. Conclusion

This study demonstrates that both seed depth and rainfall significantly influence the germination and productivity of *Bromus rigidus*. Seeds planted at a depth of 5 cm exhibited the highest productivity, balancing moisture retention and oxygen availability. Increased rainfall (500 mm/year) enhanced germination, biomass, and seed production, while moderate rainfall (250–350 mm/year) highlighted the species' drought tolerance. Shallow planting depths resulted in higher germination but lower productivity, while no germination occurred at 10 cm depth due to oxygen and moisture limitations. These findings suggest that moderate seed depth and adequate irrigation can optimize *Bromus rigidus* productivity in arid regions. Future research should validate these results in field conditions and explore their broader applicability to other species.

8. Acknowledgments

I would like to express my sincere gratitude to Professor Goff Hide and Mr. Alun Hughes from the University of Salford, Manchester, UK, for their invaluable assistance and support throughout this study. Their guidance and expertise were instrumental in facilitating the research process.

9. References

[1] Llamas, F., & Acedo, C. (2019). Typification of eight current and seven related names and a new section in the genus Bromus (Bromeae, Pooideae, Poaceae). PhytoKeys, 121, 53–72. https://doi.org/10.3897/phytokeys.121.30254

[2] Kleemann, S. G. L., & Gill, G. S. (2009). Population ecology and management of rigid brome (*Bromus rigidus*) in Australian cropping systems. Weed Science, 57(2), 202–207. https://doi.org/10.1614/WS-08-121.1

[3] Gomes, V. E. de V., Lindsey, L. E., & Mesquita, R. O. (2023). Effect of soil type and sowing depth on the germination and early growth of two grain amaranth cultivars. Agrosystems, Geosciences & Environment, 6(3), Article e20386. https://doi.org/10.1002/agg2.20386

[4] Jahantab, E., Yazdanshenas, H., Saray, A. A., & Dehghanian, M. (2022). Seed burial depth, seedling emergence, and height as affected by animal trampling in marl soils. Plant Ecology, 223(4), 493–506. https://doi.org/10.1007/s11258-021-01213-6

[5] Bu, L., Liu, J., Zhu, L., Luo, S., Chen, X., Li, S., Hill, R. L., & Zhao, Y. (2013). The effects of mulching on maize growth, yield, and water use in a semi-arid region. Agricultural Water Management, 123, 71–78. https://doi.org/10.1016/j.agwat.2013.03.015

[6] Sosnoskie, L. M., Hanson, B. D., & Steckel, L. E. (2020). Field bindweed (Convolvulus arvensis): “All tied up.” Weed Technology, 34(6), 916–921. https://doi.org/10.1017/wet.2020.61

[7] Baye, E., Ebirahim, Z., Kasahun, N., Wasyihun, N., Siyum, K., et al. (2020). Effects of planting depth on germination and growth of faba bean (Vicia faba L.) at Fitche, Oromia National Regional State, Central Ethiopia. American Journal of Agriculture and Forestry, 8(3), 58–63. https://doi.org/10.11648/j.ajaf.20200803.11

[8] Kleemann, S. G. L., & Gill, G. S. (2006). Differences in the distribution and seed germination behaviour of populations of *Bromus rigidus* and *Bromus diandrus* in South Australia: Adaptations to habitat and implications for weed management. Australian Journal of Agricultural Research, 57(2), 213–219. https://doi.org/10.1071/AR05089

[9] Penny, G. M., & Neal, J. C. (2003). Light, temperature, seed burial, and mulch effects on mulberry weed (Fatoua villosa) seed germination. Weed Technology, 17(2), 213–218. https://doi.org/10.1614/0890-037X(2003)017[0213:LTSBAM]2.0.CO;2

[10] Gleichsner, J. A., & Appleby, A. P. (2017). Effect of depth and duration of seed burial on ripgut brome (Bromus rigidus). Weed Science, 37(1), 68–72. https://doi.org/10.1017/S0043174500053713

[11] Narwal, S., Sindel, B.M. & Jessop, R.S. Dormancy and longevity of annual ryegrass (Lolium rigidum) as affected by soil type, depth, rainfall, and duration of burial. Plant Soil 310, 225–234 (2008). https://doi.org/10.1007/s11104-008-9649-6

[12] Chauhan, B. S., & Johnson, D. E. (2009). Influence of tillage systems on weed seedling emergence pattern in rainfed rice. Crop Protection, 28(12), 994–1001. https://doi.org/10.1016/j.cropro.2009.10.010

[13] Nathan, R., Schurr, F. M., Spiegel, O., Steinitz, O., Trakhtenbrot, A., & Tsoar, A. (2008). Mechanisms of long-distance seed dispersal. Trends in Ecology & Evolution, 23(11), 638–647. https://doi.org/10.1016/j.tree.2008.08.003

[14] Chauhan, B. S., Gill, G., & Preston, C. (2006). Seed germination and seedling emergence of threehorn bedstraw (Galium tricornutum). Weed Science, 54(5), 867–872. https://doi.org/10.1614/WS-06-061R.1

[15] Kering, M. K., Huo, C., Interrante, S. M., Hancock, D. W., & Butler, T. J. (2013). Effect of various herbicides on warm-season grass weeds and switchgrass establishment. Crop Science, 53(2), 629–635. https://doi.org/10.2135/cropsci2012.04.0252