Original research article

OPTIMIZING OF CULTIVATION AND ESTABLISHMENT TECHNIQUES FOR *Taverniera nummularia* IN THE ARID REGIONS OF IRAN

Alternative Crops and Cultivation Practices

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SUMMARY

This research delved into the cultivation and establishment methods of *Taverniera nummularia*, a native pasture species found in the arid regions of southern Iran, over a three-year study period. Initially, seeds of this species were gathered from natural habitats and their viability was assessed. The seed germination percentage saw an increase with the application of scarification treatment. A randomized complete block design with three replications was employed to compare two plant growing methods: direct seeding (in the field) and transplanting seedlings grown in the nursery. Both methods were implemented at Khuzestan Agricultural and Natural Resources Research and Education Center located in Baghmalek city, southern Iran. Seed germination percentage, plant establishment percentage, and dry matter (fodder) production were measured and statistically analyzed. Seed germination percentage increased up to 78.7% with the application of scarification treatment, in contrast to the germination percentage of 14.3% observed in control (without scarification). There was a statistically significant difference in seed germination percentage between the two growing methods. Germination percentages for the seeds sown in pots in nursery and those sown directly in the field were 69.9% and 50.0%, respectively. Only 8.9% of plants seeded directly in the field were established, whereas this figure rose to 47.5% for plants established through transplanting seedlings. Furthermore, fodder production following the seedling method surpassed that of the direct seeding method with 48.2 and 12.3 g/m^2, respectively. This study indicates the potential for incorporating native pasture species into agricultural production systems as a strategy to mitigate limitations caused by extreme drought and temperature shocks.

KEYWORDS: arid regions, fodder plants, germination, native pasture species, seeding, seedling, *Taverniera nummularia*

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INTRODUCTION

Many scientists contend that both natural phenomena, such as climate change, and human-induced factors, such as overgrazing, are contributing significantly to the desertification of vast swathes of our planet (Akiyama & Kawamura, 2007). Studies have shown that in warm-temperate and subarid conditions, anthropogenic activities are the primary drivers of desertification (Zalibekov, 2011). In semi-arid and arid regions, plants not only serve as the primary defenders against desertification but also play crucial roles in preserving soil fertility, enhancing vegetation diversity, maintaining ground cover, and contributing to biomass (Pei et al., 2008). Moreover, these plants can serve as vital fodder sources, playing a critical role in the economic well-being of these regions by bolstering local livelihoods (Parsons, 2012) alleviating the unsuitability of the salinity of the soil (Hasnain et al., 2023). However, conventional pasture species struggle to thrive in such extreme conditions, necessitating the evaluation of desert-adapted plants like *Taverniera nummularia*. This study aims to assess the viability of different cultivation methods for *Taverniera nummularia*, with implications for land management and biodiversity conservation in arid regions.

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Given the extreme conditions of their natural habitats, the growth of conventional pasture species becomes impractical, necessitating the evaluation and comparison of desert-adapted plants (Vogel & Jensen, 2001). Survival rates following planting can significantly differ among desert and steppe pasture grass species (Adnani et al., 2009). Criteria for assessing the success of fodder species in desert environments include establishment rate, vegetation percentage, freshness, fodder yield, and palatability (Moslehi Jouybari et al., 2022). Moreover, species with different growth rates under normal conditions may exhibit contrasting behaviors in drought conditions, highlighting the need to delineate the boundaries of arid region harshness (Fernández & Reynolds, 2000).

Studies on pasture species growth and establishment in Iran's Central Province's steppe areas underscore the significant impact of species type on survival and establishment rates. While some research suggests that native species outperform non-native counterparts (Ardestani et al., 2015), native status doesn't invariably equate to higher efficacy. A thorough evaluation of numerous plants is necessary to assess their germination and establishment potential (Tilley & John, 2006). Species suitability alone isn't sufficient for successful establishment in these regions (Munda & Pater, 2003); even species well-suited for revitalizing regions require careful consideration. For instance, aerial seeding has shown limited effectiveness (Zheng et al., 2005), and soil salinity parameters must be taken into account (Zinchenko & Golovatyuk, 2013).

Several influential factors affect shrub establishment in arid regions, including salinity, water availability, heat, seed species, soil structure and type, planting time, plant competition, insects, seeding method, and grazing management (Malcolm & Swaan, 1989). In various arid regions of Iran, plant germination and survival to produce the next generation's seeds pose significant challenges (Jabarzare et al., 2010). While plantation conditions and parameters may vary, moisture remains the critical factor, serving as the primary criterion for evaluating other parameters (Malcolm, 1972). Adequate water is essential for maintaining plant turgidity, survival, and growth, as dehydration can lead to severe cellular changes and disorganization (Ashraf et al., 2006). Studies showed that plants of arid regions in Iran significantly depend on the rainfall patterns and the percentage of establishment had a direct relationship with the amount and proper distribution of rainfall (Filehkesh et al., 2006).

Deeper-rooted desert pasture species tend to exhibit better establishment, survival, vitality, and growth compared to other species in the region (Malcolm, 1972). A robust vegetative character and root system enable moisture absorption from various soil depths (Sanadgol, 2019). Some studies suggest that planted seeds only receive upward-migrating water during evaporation (Tadmor et al., 1969). However, excessive burial depth can suppress seeds, with many deeply buried seeds failing to germinate (Tobe et al., 2005). Thus, a thin soil layer may suffice to maintain seed moisture and facilitate establishment if other plantation parameters are suitable (Abtahi, 2016). Identifying the optimal planting time and method for each species in hostile steppe regions is crucial, as planting time determines rainfall reception, and rainfall amount and distribution in the first year directly affect plant establishment (Mirhaji et al., 2012).

A substantial portion of Iran's pastures has been depleted due to various factors, including extensive grazing and climate change, endangering many pasture plants and drastically reducing their populations. To restore stability to these pastures, it's imperative to modify and revitalize them by selecting appropriate species and implementing optimal cultivation and establishment methods. This research aims to determine the most suitable method and experimental parameters for cultivating a desert species, *Taverniera nummularia*. By providing a comprehensive understanding of efficient cultivation methods and accurate comparative predictions of establishment outcomes and fodder yield, this research can aid regions in preserving their pastures, combatting desertification, and safeguarding regional biodiversity.

MATERIAL AND METHODS

The study was performed at the Khuzestan Agricultural and Natural Resources Research and Education Center located in Baghmalek city, southern Iran. The research involved: gathering *Taverniera nummularia* seeds from their natural habitats (2013 - 2016), analyzing seed germination without (control) and following scarification (treatment), 2014 - 2016; and assessing two cultivation methods (direct field seeding and transplanting seedlings), 2014 - 2016. Therefore, all results reported in this paper represent mean values calculated over a three-year period. The assessment criteria for the cultivation methods included plant establishment percentage and fodder yield .

Seed collection and laboratory evaluations

The seeds were collected from the area of Baghmalek city (31°31′29″N 49°53′13″E) with an average elevation of 917 m above sea level, with semi-arid climate. Both the flowering period and seed ripening in *Taverniera nummularia* are extended from mid-spring to late summer. The seeds were collected at regular intervals few times during late June. Given the varying sizes of the plants in their natural habitat, the amount of seed produced by each individual plant differed. Therefore, seeds were collected randomly from various plants and then bulked (mixed) together. The ripe seeds were collected each time from beneath approximately 50 to 70 plants to ensure sufficient genetic diversity. It is worth noting that due to the overexploitation of rangelands and the ongoing extinction of palatable species including the rangeland species under study, seeds were collected from nearly all available plants in the surrounding natural habitat of the research center. The seeds before and after germination are shown it the Pictures 1 and 2. To conduct the tests, healthy and mature seeds were selected at random. Until September, the seeds were kept in the seed bank's cold storage at a temperature of 3.0 ± 1.0°C. The seeds were evaluated according to International Seed Testing Association (ISTA) protocols, which involves assessments of seed viability, purity, and 1000-seed weight (International Seed Testing Association, 1976). Following storage, the seeds underwent treatment at the seed technology laboratory. Germination tests were conducted by placing primed seeds into a germinator at 20.0°C.

Picture 1. Winnowed seeds gathered from the natural habitat

Picture 2. Seed appearance after scarification treatment

In order to investigate the possibilities for improving germination, the seeds were germinated: without (control) and following the scarification (treatment). The scarification was chosen among other treatment methods for desert plants (Vilela & Ravetta, 2001), due its simplicity, practicality, and significant enhancement of seed germination rates. Scarification treatment with sandpaper was chosen based on its simplicity and effectiveness.

Plantation

To determine the optimal establishment method for maximizing fodder yield, this study compared direct field seeding against the transplantation of nursery-grown potted seedlings. The selection of a plantation method is vital in this region given the hot, arid climate and recent climate shifts, which have resulted in decreased and poorly distributed rainfall. These environmental challenges are particularly acute during April and during the early onset of spring heat waves, making robust early establishment essential for plant survival.

For the direct seeding treatment, planting pits were constructed in November following the onset of the rainy season. Seeds underwent scarification treatment before being sown into these pits; however, due to the cooler winter environment and the species' preference for warmer temperatures, germination was delayed until February. Throughout this process, soil compaction over the seeds was strictly avoided, as compacting sandy-loam and clay-loam soils post-seeding has been shown to have no significant impact on seedling establishment (Springfield & Bell, 1967).

In contrast, the nursery-based approach began in September to take advantage of favorable ambient temperatures. The nursery was located adjacent to the main experimental field to ensure the environment remained similar to the species' natural habitat. Following scarification, seeds were sown into small polyethylene pots, where germination occurred rapidly within 7 to 10 days. Seedling growth continued until the onset of colder weather, at which point growth stagnated. To mitigate the risk of exposure to sub-zero temperatures, these seedlings were transplanted into the field in early February. The transplantation technique involved removing the plastic coverings while retaining the soil from the pots, a method favored over bare-root transplantation due to its higher success rate (Malcolm, 1972).

The trial was arranged in a completely randomized block design with three replications. The experimental layout involved eight rows of seedlings per block, with the two peripheral rows serving as buffers to minimize edge effects. Seedlings were established at a 1 m spacing, a configuration selected based on the anticipated mature canopy spread of the species. Schematics of the seeding method and visual depictions of the seedlings prior to transplantation and after establishment are illustrated in Pictures 3 through 9.

The selected planting site for the project closely resembled the natural habitat of *Taverniera nummularia*, considering ecological conditions and soil type due to the fact that the plant can grow in the region naturally. This genus is associated with "seasonally dry tropical and subtropical desert, shrubland and bushland able to thrive in dry harsh

Picture 3. Planting site preparation

Picture 4. Direct planting of the seeds in the soil

Picture 5. Planting seeds in the pots in the nursery

Picture 6. Seedlings in the nursery

Picture 7. Planting the seedlings in the soil

Picture 8. Establishing the seedlings in the soil

Picture 9. Established seedling

sites" (POWO, 2024) with "salinity soil" (Hasnain et al., 2023). Additionally, measures were taken to protect the plants from physical damage and unforeseen threats such as grazing of the wild and domestic animals. The data analysis focused on the percentage of established species, implying fully developed plants that are capable of producing next-generation seeds. Plant establishment was assessed in through visual plot inspection, quantifying the proportion of successfully established individuals relative to the total number of sown or transplanted plants. This parameter indicates the potential for species regeneration within the area.

Finally, the fodder yield was measured. It is the dry matter (g) harvested from the entire plantation site. Forage harvesting was conducted in early May during the flowering stage. The process involved harvesting the entire plant by cutting at the root crown, after which the stems and leaves were chopped and dried for analysis.

Data were analyzed using analysis of variance (ANOVA), and mean comparisons were performed. All statistical analyses were conducted with SAS software.

RESULTS AND DISCUSSION

Following preparation and planting, the evaluation process commenced, focusing on various aspects of *Taverniera nummularia* plantation. This included assessing the impact of seed treatment methods on germination rates and overall plant establishment. The 1000-seed weight was 5.3 g.

Seed germination percentage with and without scarification treatment

After acquiring seeds from natural habitats under desired conditions, their germination was assessed. By assessment of germination of the seed, it was found that the seed germination percentage was 14.3%. Statistical analysis revealed a significant difference, with a 1.0% error margin, between the germination of untreated seeds and seeds subjected to scarification treatment using sandpaper (Table 1). A comparison of mean values between the groups demonstrated that employing scarification treatment on seed coats resulted in 78.7% in germination percentage (Figure 1).

Table 1. Analysis of variance for seed germination percentage, without (control) and with scarification (treatment)

Sources of variation	Df	Sum of squares	Mean squares	F
Seed treatment	1	10378.06	10378.06	809.22**
Test error	8	102.60	12.825	
Total	9	10480.66		

Df–degrees of freedom, **–significant at the 0.01 level of probability

These results align with previous studies on leguminous species where mechanical abrasion proved superior to other methods. Some studies reported that mechanical scarification using sandpaper significantly improved germination by effectively removing the thick waxy layer of the seed coat in various forage legumes (Kimura & Islam, 2012).

Although studies showed that scarification can have significant effect on the germination of the seeds, it is crucial to conduct such experiments for each plant species and each scarification setting independently, as seed coat responses are not uniform across the plant kingdom (Araujo et al., 2017; Hernandez et al., 2020). Also it should be mentioned that, while sandpaper was assumed the optimal solution in this study, it can be ineffective for other species (Rocha et al., 2022) and other methods can be more effective. This substantial improvement holds critical implications for the success of arid land plantation and soil stabilization projects.

Germination percentage in two planting methods: direct seeding in the field and seeding in pots in the nursery

In order to determine the optimal planting method for *Taverniera nummularia*, the direct seeding in the field and transplanting seedlings grown in nursery were performed. The results of the analysis of variance indicated significant differences ($p < 0.01$) between the two planting methods in terms of germination percentage, plant establishment, and fodder performance (Table 2). The germination percentage for direct seeding in the field was 50.0%, and 69.9% for seeding in pots in nursery (Figure 2).

Table 2. Analysis of variance for seed germination percentage, plant establishment, and fodder performance for two planting methods

Sources of variation	Df	Sum of squares		
		Germination	Establishment	Fodder yield
Planting method	1	595.01*	2007.51**	1926.04**
Replication	2	92.04 ^{ns}	6.45 ^{ns}	9.5 ^{ns}
Test error	8	15.04	8.073	4.667
Total	11	702.09	2022.033	1940.207

Df–degrees of freedom, ns, *, **–insignificant, significant at the 0.05 and 0.01 levels of probability, respectively

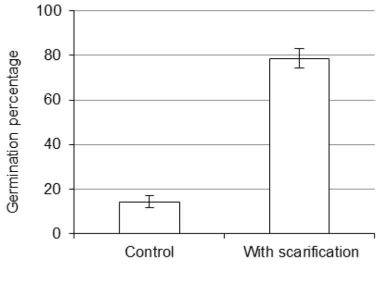

Figure 1. Comparison of the average germination percentage in *Taverniera nummularia* species for control group and scarification treatment group. Error bars indicate standard errors of means

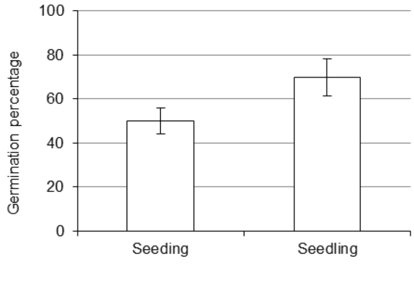

Figure 2. Comparison of the germination percentage in *Taverniera nummularia* planted by direct seeding in the field (Seeding) and transplanting seedlings grown in the nursery (Seedling). Error bars indicate standard errors of means

The plant establishment percentage

The analysis of variance results indicated a significant difference between the two planting methods regarding the plant establishment percentage (Table 2). Upon comparing the averages, it was evident that 8.9% of the seedlings were able to establish when the direct seeding in the field was used, whereas the seedling transplantation method resulted in 47.5% established plants (Figure 3).

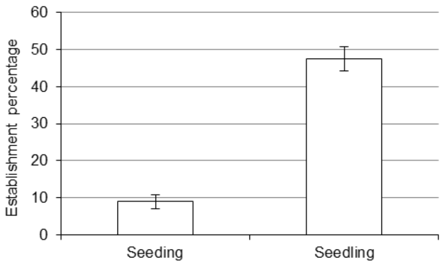

Figure 3. Comparison of the average establishment percentage in *Taverniera nummularia* species following the direct seeding in the field (Seeding) and transplanting seedlings grown in the nursery (Seedling). Error bars indicate standard errors of means

In the seeding method, a significant portion of emerged seedlings perished by mid-May due to early onset of high temperatures and insufficient spring rainfall. In contrast, 47.5% of plants were successfully established using the seedling method. This higher success rate can be attributed to the seedlings spending their initial and delicate growth stages in the nursery. As a result, upon transplantation, these seedlings, being four months old, were able to capitalize on favorable late winter and early spring conditions, enabling them to develop robust aerial organs and roots, produce more dry matter, and better utilize soil resources and moisture from lower soil layers. Consequently, they exhibited improved resilience to challenging summer conditions.

Fodder yield

There was a statistically significant difference between the two planting methods in fodder yield, i.e. dry matter production (Table 2). On average, the yield of dry fodder obtained by transplanting seedlings amounted to 48.2 g/m^2, whereas it was 12.3 g/m^2 in the seeding method (Figure 4).

Some studies approved that seeding method has very low and unreliable establishment, with final survival often around 5.0-15.0% and sometimes close to zero under harsh desert conditions; while, planting nursery-grown seedlings bypasses the vulnerable germination phase and achieves much higher survival rates, commonly in the range of 50.0–90.0% when basic care and protection are provided (Cramer, 2008). The transplanted plants of globe artichoke showed better root and shoot growth in comparison to seeding method plant, 6.0% for the first year and 34.0% for the second year (Leskovar & Othman, 2021), while for sugar beet the difference between the seeding and seedling was 45.0% (Khozaei et al., 2020).

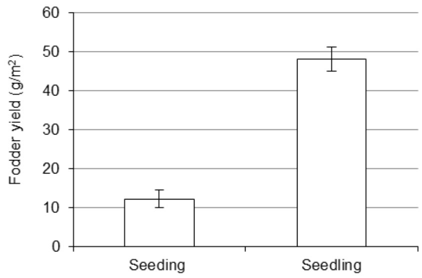

Figure 4. Comparison of the average average fodder yield one year after plantation. . Error bars indicate standard errors of means

CONCLUSIONS

It was observed that the scarification treatment effectively rendered the *Taverniera nummularia* seed coat permeable to water without adversely affecting the seed embryo, establishing it as the most effective treatment for accelerating seed germination.

The higher seed germination percentage observed in the transplanted seedling method can be attributed to the controlled conditions in the nursery, including soil type, cultivation bed, and moisture supply, compared to direct seeding in the field. Conversely, in the direct seeding method, many seeds may fail to germinate due to a lack of control over environmental conditions.

Given the climatic conditions of Khuzestan province, characterized by reduced and unevenly distributed rainfall and early onset of extreme heat in summer, with air temperatures reaching 50°C, which hinder successful direct seeding; it is recommended to utilize the transplanted seedling method for species with natural germination occurring towards the end of winter. Employing the seedling method ensures optimal utilization of valuable pasture seeds, facilitates better establishment, and ultimately leads to more successful vegetation improvement and tropical pasture revitalization programs.

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UVOĐENJE U PROIZVODNJU VRSTE *Taverniera nummularia* U SUŠNE REGIONE IRANA

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Cilj rada je bilo ispitivanje metoda gajenja i mogućnosti uvođenja u proizvodnju biljke *Taverniera nummularia*, autohtone vrste koja raste na pašnjacima sušnih regiona južnog Irana. Istraživanje je sprovedeno u Khuzestan Agricultural and Natural Resources Research and Education Center-u smeštenom u gradu Baghmalek, na jugu Irana. Seme je sakupljeno iz prirodnog staništa i ispitana mu je klijavost. Utvrđeno je da tretman skarifikacijom pozitivno utiče na klijavost semena, koja je iznosila 14,3% i 78,7% kod netretiranog i tretiranog semena, po redosledu. Upoređene su dve metode gajenja biljaka u polju: direktna setva i presađivanje sadnica proizvedenih u zatvorenom prostoru. Analizirani su: procenat klijavosti semena, procenat primanja biljaka nakon presađivanja i prinos suve materije (krme). Utvrđena je značajna razlika u klijavosti semena kod dve metode gajenja: 50,0% kod direktne setve i 69,9% kod setve u saksije u zatvorenom prostoru. Dok se primilo samo 8,9% biljaka koje su nikle iz direktne setve, procenat primljenih presađenih biljaka je bio 47,5%. Prinos suve materije je kod biljaka iz direktne setve bio 12.3 g/m^2, a kod presađenih biljaka 48,2 g/m^2. Istraživanje ukazuje na potencijal za uključivanje autohtonih vrsta koje rastu na pašnjacima u sisteme poljoprivredne proizvodnje kao strategije za ublažavanje posledica ekstremne suše i temperaturnih šokova.

KLJUČNE REČI: autohtone vrste pašnjaka, klijanje, krmno bilje, sadnica, setva, sušni regioni, *Taverniera nummularia*

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