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Productivity Evaluation of Four *Medicago sativa* Cultivars under Two Water Regimes (Irrigated and Non-Irrigated) and Two Soil Types at Bathurst Research Station in the Eastern Cape Province, South Africa

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Abstract

Medicago sativa (lucerne) is a perennial and drought tolerant fodder crop which is widely used as feed for livestock in South Africa. This study evaluated four lucerne cultivars under two water regimes and also determined the effect of soil type on lucerne biomass production. To determine dry matter production per cultivar per treatment, a random grid (quadrant) sampling method was used and all biomass within that radius was cut to 5 cm above the ground level in each plot. All biomass sampling was done just before regrowth commences. Biomass data collection on four lucerne cultivars belonging to different dormancy groupings (WL 711, WL 525 HQ, KKS 9911 and SA Standard) were collected seasonally under different soil types on both irrigated and non-irrigated plots and analysed. Soil type (site) had a significant ($P < 0.05$) effect on the overall quantity of dry matter produced as more dry matter was produced in site 2 (S2) in comparison to site 1 (S2). Different levels of water application (moisture supplementation) also affected the quantity of dry matter produced in each soil type. The once-a-month irrigation treatment (Ir1) led to the production of superior dry matter yield on SI even though the effect was

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not significant. In S2 twice a month irrigation treatment (Ir2) produced the highest dry matter, however, this effect was significant (P < 0.05) only in comparison with zero irrigation (Ir0) treatment. Cultivar 3 (KKS 9911) was the least productive cultivar in S1, while the same cultivar was the least productive cultivar in S2. These findings show that both soil type and irrigation levels had a significant (P < 0.05) effect on the total dry matter production of the tested Lucerne cultivars belonging to different dormancy groupings.

Keywords

Biomass, Cultivar, Dry Matter, Dormancy Groupings

1. Introduction

Medicago sativa (lucerne/alfalfa) is a perennial fodder crop belonging to the *Fabaceae* family [1]. It is suitable for hay, silage and grazing for livestock and has a high fodder quality and digestibility. *Medicago sativa* is highly palatable and produces large quantities of dry matter (DM), especially under irrigation and thus, it is regarded as the best and most commonly utilised pasture and hay plant in South Africa [2] [3]. In the semi-arid areas with annual rainfall exceeding 500 mm, lucerne is cultivated as a rainfed crop and used for grazing [4]. It is estimated to have a productive lifespan of at least six years or longer [5]. Lucerne cultivar selection is one of the most important factors determining the production potential in a particular environment and is selected based on the amount of dry matter it can produce. Its management is also key in bringing that potential to fruition. The type of a selected cultivar directly affects DM quantity and quality, pest/disease tolerance and stand life [6] [7]. Stand persistence is also an important factor to consider when selecting a cultivar, particularly when *M. sativa* is to be produced for a number of consecutive growing seasons, as is the case for most producers [7]. The longer the stand persists is, the seed and establishment cost becomes less important [8]. Environmental and phenological factors, such as season, stage of growth and soil fertility status affect the nutritive characteristics of forages such as Lucerne [9]. Most livestock farmers or pasture producers in most parts of the Eastern Cape Province are confronted with limited or no access to irrigation water as well as producing pastures from marginal soils, these conditions are further exacerbated by climate change. while the aforementioned challenges are faced by livestock farmers the need to bridge the forage deficit during dry season still remains to be fulfilled by livestock or pasture producers. Therefore, better knowledge on how the four selected lucerne cultivars respond to variation in soil type and moisture levels is required to assist farmers on cultivar selection and best lucerne management practices under different soil types. The aim of the study was to determine the effect of soil type and moisture levels on total dry matter yield produced by four lucerne cultivars planted in the Eastern Cape Province, South Africa.

2. Materials and Methods

2.1. Study Site

The trial was conducted at Bathurst Research Station which is located at 33˚30'S latitude and 26˚49'E longitude, at 708 m above sea level. The annual rainfall is 624 mm with the temperature ranging between 13˚C - 29˚C. The vegetation of the area is Kowie Thicket which is characterized by tall-grown thickets. It is dominated by succulent Aloes and Euphorbias and is comprised of woody lianas and thorny shrubs [10].

2.2. Experimental Procedure

Lucerne trial was established at two sites within the research station. The different treatments were irrigated and non-irrigated plots. Four different cultivars (*i.e.* WL 711, WL 525 HQ, KKS 9911 and SA Standard) representing all the four major dormancy groupings were used as shown in (**Table 1**).

SA Standard was used as the control. All plots were 3 m × 3 m in size and were 12 meters apart. The trial was established in March-April 2018 as a 2X3 X4 factorial design replicated three times.

Before planting, soil samples were collected at random points from each site up to a depth of 15 cm to determine both chemical and physical properties of the soil prior to planting (**Figure 1**). All soil samples were analysed at Döhne laboratory for soil pH, organic carbon (OC), total nitrogen (TN), exchangeable cations and available phosphorus using the Ambic-2 method [11] [12], and standard procedures described in soil science of South Africa (1990). Seeds were inoculated with a proper strain of inoculum (rhizobium bacteria). The seed in the irrigated plots was planted in rows of 150 mm apart and the seeding rate of 15 kg·ha^{-1} and it was rolled immediately after sowing for better contact between seed and soil. In the non-irrigated plots, the rows were 300 mm apart and the seeding rate was 5 kg·ha^{-1} [13] [14].

Figure 1. Soil sampling in S2 (Oakleaf soil form) under irrigation or non-irrigated plots at Bathurst Research Station, in the Eastern Cape Province.

Table 1. Dormancy groupings of the tested lucerne cultivars.

Varieties	Dormancy Rating	Explanation
(C1) SA Standard	(6)	6 - 7 varieties are generally termed winter active (WA) or alternatively semi-winter active. This group offers the most flexibility and productive potential for longer-term, general-purpose grazing or fodder production.
(C2) WL 711	(10)	Dormancy 8 - 10 types are termed highly winter active (HWA). They may suit a short-term pasture phase to capture some year-round grazing opportunities, although are most frequently used where fast rotation fodder production is being practised.
(C3) KKS 9911	(9)	Same as above
(C4) WL 525 HQ	(8)	Same as above

The choice of cultivars was based on the dormancy groupings that were evaluated for their performance in the Eastern Cape. The control treatment was also subjected to irrigation and fertiliser treatments. A pre-planting fertiliser (lime) was also incorporated into the soil prior to the last seedbed preparation. Sprinklers were used to supplement moisture on the irrigated plots and no irrigation was applied in non-irrigated plots. The moisture supplementary rates were as follows: 0 mm (*i.e.* I0), 30 mm (*i.e.* I1) and 60 mm (*i.e.* I2) per month for irrigated plots, respectively. The irrigation processes were done on a bi-weekly basis, watering 30 mm of water per irrigation. The amount of water per irrigation and the dates at which the irrigation was applied were recorded annually. For the non-irrigated plots, the rainfall dates, the amount of rain was recorded on at monthly basis. The total number of irrigations and rainfall per annum was calculated and recorded.

2.3. Biomass Data Collection

For determination of dry matter production per cultivar in each treatment, a random grid (quadrant) sampling method (where a circular quadrant of 1 m^2 size adjusted to a 5 cm height was thrown on the plots randomly) was used and all biomass within that radius was cut to a 5 cm above the ground level in each plot. The density of plants was determined by randomly setting out 1 m^2 circular quadrats in each plot and physically counting all plants in the quadrate. All cuttings or biomass sampling were done just before regrowth commences. The harvested biomass for each cultivar was separated using clean packs, weighed and dried at 70˚C for 48 hours then weighed for dry mass to determine the moisture content. A further laboratory test was done to determine biomass quality. This involved the determination of Crude protein (CP), Total Digestible Nutrients (TDN), phosphorus, potassium and calcium content of the pasture. Determination of essential micronutrient levels (*i.e.* Cu, Fe, Mn, Zn and Ca) was also done. A 250 g grab sample per plot was collected for quality analysis purposes annually.

2.4. Data Analysis

All data collected was statically analysed by making use of both descriptive and inferential statistical techniques using the Statistical package for the Social Sciences (SPSS), version 25. Analysis of Variance (ANOVA), the repeated option of PROC GLM including Multifactor ANOVA where dry matter production per cultivar was a dependent variable while moisture supplementation rates, cultivar and soil type were factors. Statistical significance was tested at 95% level with all results with $P < 0.05$ considered to be statistically significant.

3. Results

The findings of the study show that the overall dry matter produced on site 1 (S1) (Wesleigh soil form) and Site 2 (S2) (Oakleaf soil form) was 2.5 tons/ha and 9.5 tons/ha, respectively (**Figures 2-4**). Therefore, S2 had a significant effect ($P < 0.05$) on the overall dry matter production as S2 produced high dry matter in comparison to S1 (**Figure 5**). The once a month irrigation treatment (Ir1) resulted in the highest dry matter yield on S1, while twice a month irrigation treatment (Ir2) produced the highest dry matter in S2, however, this effect was significant ($P < 0.05$) only in comparison with zero irrigation (Ir0) (**Table 2**). Although the four tested lucerne cultivars seemingly produced higher dry matter yields in S2 than in S1 these differences were all not significant. Cultivar KKS 9911 (C3) was the least productive cultivar in both S1 and S2 in comparison to all the cultivars. The most productive ($P < 0.05$) cultivar in both S1 and S2 was cultivar 1 (SA standard) than all other cultivars (**Table 3**).

Figure 2. Early stages of lucerne establishment in site 1 (Wesleigh soil form) under irrigated or non-irrigated plots at Bathurst Research Station, in the Eastern Cape Province.

Figure 3. Late stages of lucerne establishment in site 1 (Wesleigh soil form) under irrigated or non-irrigated plots at Bathurst Research Station, in the Eastern Cape Province.

Figure 4. Early stages of lucerne establishment in site 2 (Oakleaf soil form) under irrigated or non-irrigated plots at Bathurst Research Station, in the Eastern Cape Province.

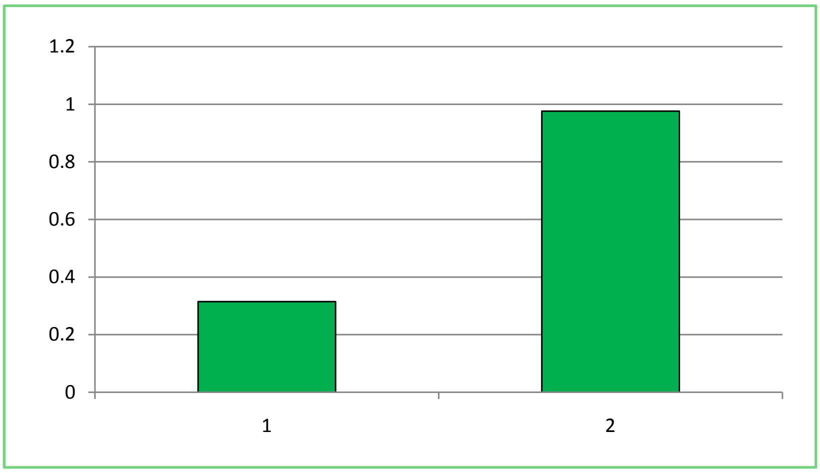

Figure 5. Overall dry matter production per site.

Table 2. Effect of water supplementation per site on DM production in kg/m^2 of lucerne.

Soil type	Irrigation	Mean	Std. error
Soil 1	Ir0	0.32^c	1.98
	Ir1	0.34^c	1.98
	Ir2	0.28^c	1.98
Soil 2	Ir0	0.77^b	1.98
	Ir1	1.03^a	1.98
	Ir2	1.13^a	1.98

Similar superscripts within the same column depict no significant difference while dissimilar superscripts within the same column depict significant ($P < 0.05$) differences in dry matter production per cultivar.

Table 3. Lucerne dry matter produced in kg/m^2 per cultivar in two soil types.

Soil type	Cultivar	Mean	Std. error
Soil 1	C1 = SA Std.	0.41^c	1.98
	C2 = WL 711	0.26^d	1.98
	C3 = KKS 9911	0.22^d	1.98
	C4 = WL 525	0.38^c	1.98
Soil 2	C1 = SA Std.	1.02^a	1.98
	C2 = WL 711	1.01^a	1.98
	C3 = KKS 9911	0.89^b	1.98
	C4 = WL 525	0. 99^a	1.98

Similar superscripts within the same column depict no significant difference while dissimilar superscripts within the same column depict significant ($P < 0.05$) differences in dry matter production per cultivar.

4. Discussion

This study was aimed at evaluating the dry matter production potential of different Lucerne (*Medicago sativa*) cultivars belonging to four dormancy groupings growing in two soil types at different moisture application levels. The general aim of the study was to evaluate the response of the four Lucerne (*Medicago sativa*) cultivars planted in two soil types on the application of different irrigation or moisture levels. The findings of the study show that the dry matter produced on S1 and S2 was 2.5 tons/ha and 9.5 tons/ha, respectively. Therefore, S2 had a significant effect ($P < 0.05$) on dry matter production as S2 produced high dry matter in comparison to S1. In terms of soil nutrient status, S1 was a below-average poor soil type while S2 was an average soil providing a conducive environment for optimum plant growth and development. The two research sites are different in terms of soil forms and soil physical characteristics; these differences did translate to significantly different levels of lucerne biomass production. It is quite clear that S2 remains the most productive site throughout the various treatments. This is ascribed to the fact that S2 is well drained and moderately deep therefore more suitable for optimum lucerne production. S1 was noted to have a shallow soil depth, signs of wetness and water logging and these characteristics are viewed as an impediment to optimum lucerne production This is comparable to the finding of the studies conducted by [10], who alluded that Lucerne dry matter production is greatly influenced by a number of environmental and phenological factors such as soil nutrient status. Soil type significantly influences the plant available water content (PAWC) and this, in turn, has an effect on potential Lucerne yield [15] [16].

Concerning cultivar evaluation, the four tested lucerne cultivars produced more dry matter in S2 while they produced less dry matter in S1. Cultivar 3 (KKS 9911) was the least productive cultivar (0.22 kg/m^2) in S1 in comparison to the rest of the cultivars, while the same cultivar C3 was the least productive cultivar (0.89 kg/m^2) in S2. Even though the most productive cultivar in both S1 and S2 was C1 (SA Standard) which was a control cultivar in this experiment, cultivar 4 (WL 525) performed well in both sites and is one of the highest ranked cultivars with regards to dormancy groupings and therefore it's good performance was expected. Winter active cultivars have abundance of soluble sugars and stress-related translation products, as well and differential accumulation of protein, DNA and RNA [2]. Such plants can produce up to 20% of their annual growth during winter by limiting the freezing occurring in extracellular spaces [3]. This finding is in line with the results published by [9], who concluded that a selected cultivar directly affects DM quantity and quality, pest/disease tolerance and stand life.

Once a month irrigation water supplementation resulted in the production of the highest dry matter yield (*i.e.* 0.34 kg/m^2) in site 1 while, twice a month (Ir2) irrigation resulted in the production of the highest dry matter (1.13 kg/m^2) in site 2. Moisture supplementation resulted in the production of the highest dry matter yield in both S1 and S2. These findings show that soil type and irrigation had a significant effect on the total dry matter production of the various tested Lucerne cultivars belonging to four dormancy groupings. This is consistent with the results obtained by [11], who argued that the growth of Lucerne is largely dependent on its ability to extract water from the soil. This was further confirmed by [16] [17] who found out that soil type significantly influenced the plant available water content (PAWC) and this, in turn, had an effect on potential Lucerne yield. It was also found that water stress, just like in any other crop, limits Lucerne production more than any other management practice. In this study, it was also evident that poor soils quickly reach a peak in terms of water holding capacity and therefore even if one increases the water supplementation the increase won't translate to increased biomass yield as is the case in S1. In good soils as in the case of S2 increased water supplementation does result in increased dry matter production.

One of the limitations of the study was the quality of water that was used to supplement moisture as it is salty water as the trial site is located in the coastal area and is not suitable for optimum plant production. The number of sprinklers that were used for water supplementation was also limited and therefore could not cover the plots well. Soil moisture content was not measured prior to the start of the trial as there were no instruments to do so due to budget constraints. For future research purposes, it would be good to conduct a similar study using better quality water and do soil moisture content measurements before the commencement of the study.

5. Conclusion

Findings of this study confirm lucerne as a high-yielding perennial species with the capacity to adjust or adapt physiologically and morphologically over a certain range of soil types, temperature and moisture to persist from generation to generation over a period of years. Lucerne is a drought-hardy, perennial pasture legume producing high-quality and quantity forage due to its root system that grows deeper and becomes more branched when grown under dry land as opposed to irrigated conditions. Cultivar selection is key when one is to produce Lucerne in poor or below-average soils. In cases where prior soil classification and testing is not done cultivars that are highly ranked in terms of dormancy grouping like cultivar 4 are recommended for farmers or producers. Even though moisture content is one of the major factors affecting plant development and growth, soil quality overrides the effects of water supplementation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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