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The Effects of Sowing Rate, Defoliation Intensity and Time of Defoliation Commencement on Vegetative and Reproductive Growth of Medic Swards

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ABSTRACT

To obtain detailed information of sowing density and defoliation intensity under more controlled conditions on herbage production and seed yield, Paraggio medic was grown on raised-beds located outdoors at the Waite Agricultural Research Institute. A split split randomised block design was used. Treatments comprised three sowing rates (densities): Low (3 kg/ha), Medium (15 kg/ha) and High (75 kg/ha) (based on pure germinating seed which gave 75, 375 and 1875 seedlings/m^2 respectively); four defoliation intensities: Control (undefoliated), Low (6 cm from ground level), Medium (4 cm) and High (2 cm) to simulate different grazing pressures and two defoliation systems of continuous (defoliation from June 1) and deferred (defoliation from June 29). The total combination for experimental blocks was:Main plots, defoliation systems (2) x Sub plots. sowing densities (3) x Sub-sub plots defoliation intensities (4) x Blocks (4) = 96 micro plots.The continuous defoliation system produced significantly higher (P<0.05) available forage as well as total pasture production (P<0.05) than the deferred. High sowing rate increased (P<0.01) forage availability and total pasture production. Medium and high defoliation intensities significantly (P<0.01) reduced available forage and total pasture production in the deferred defoliation system. Seed production was adversely affected by defoliation intensity.

Keywords: Medic, Sowing rate, Defoliation, Forage production, Seed production

INTRODUCTION

Sowing rate determines the seedling density and pasture growth rate during the autumn/winter period when livestock feed is the limiting factor to pasture-livestock production systems (Carter 1986). Sowing rate may generally affect the growth and development of the pasture throughout the growing season (Adem 1977; de Koning 1990; Squella 1992). Plant density regulates the growth pattern of annual medics and subterranean clover communities (Adem 1977; Silsbury and Fukai 1977; Silsbury *et al.* 1979; de Koning 1990; Squella 1992). Many workers consider that measurement of pasture production in terms of animal production is the only realistic approach for pasture research. However, if the effects of intensity of defoliation are to be separated from the effects of frequency of defoliation studies using some form of cutting or artificial defoliation is necessary. Clipping studies can only approximate grazing studies; the effects of animal selectivity, animal treading (Edmond 1963) and the return of dung and urine (Watkin 1957) are missing under simulated grazing (Sears 1951). Frequent defoliation enhanced branching in sub clover (Rossiter 1976). However, the possibility exists that cutting also caused a faster rate of leaf and inflorescence production on individual branches. In the case of annual medics, as the intensity of defoliation increases, yield of shoot tissue decreases

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(Tow-1981). Cutting at 5 cm height gave most herbage production although there was no significant difference between seed production in this treatment, 8 cm and uncut treatments. Similar results have been obtained by varying the frequency of defoliation, the greatest reductions in yield having occurred where the defoliations have been most frequent. Lowe and Bowdler (1980) suggested that lax cutting in subsequent defoliation could reduce damage from severe cutting management.

In conclusion, defoliation has a dramatic influence on the productivity of annual legume pastures. Production differences between cultivars may be eliminated in some situations by defoliation (Collins *et al.* 1983). Defoliation by mechanical methods has provided some information about the basic responses of medic to defoliation. However, mechanical defoliation is not totally representative of the field situation under the influences of grazing livestock. Plant density and defoliation interactions for medic in relation to herbage production are not fully understood, yet both factors have great influence on the herbage production of medic-based pastures.

Since plant density has such an important influence on the productivity of medic pasture it is necessary to include this factor in management experiments.

The objectives of this experiment were to examine the effects of sowing rate, defoliation intensity (simulating grazing pressure) and time of commencement of defoliation (simulating grazing deferment) on the growth, vegetative plant characters and seed production of Paraggio barrel medic.

MATERIALS AND METHODS

Design and treatments: Paraggio barrel medic *Medicago truncatulla* var. Paraggio was grown in raised-beds located outdoors at the Waite Agricultural Research Institute. Two defoliation systems were used, viz.: continuous (defoliation commenced as plants reached 20 cm height) and deferred (defoliation commenced 4 weeks after commencement of continuous defoliation) as the main effects. In the sub plots, treatments consisted of factorial combination of three sowing rates (Low= 3 kg/ha, Medium =15 kg/ha and High = 75 kg/ha) based on pure germinating seed which gave a-potential of 75, 375 and 1875 seedlings/m^2 respectively, and four defoliation intensities (Control (non defoliated), Lenient = 6 cm, Moderate = 4 cm and Severe 2 cm from ground level) to simulate different grazing pressures. The medic was sown in micro-plots of 3600 cm^2 (60x60 cm) and arranged in a completely randomised block design with a split-split plot treatment structure and four replications.Each replication was contained in one of four raised-beds. Main plots were the two defoliation systems, split plots were the three sowing rates, split-split plots, the four defoliation intensities. Treatments were assigned at random within each block. The total combination for each experimental block comprised: Defoliation systems (2) x sowing rates (3) x Defoliation intensities (4) x Blocks (4) = 96 micro plots

Preparation of the experimental site: The permanent raised beds filled with sandy loam soil were scraped to remove any legume or weed seed before applying a complete mineral-mix fertiliser at a rate of 200 kg/ha. Seed was broadcast evenly by hand on April 16, 1994 and then covered with the 1 cm of the same soil type previously removed before sowing. After sowing, the experimental area was covered with a thin layer of about 0.5 cm of steam-sterilised coarse sand, in order to reduce surface hardness. The beds were hand watered with a fine spray as required during the entire period of the study, weeds being removed continuously by hand.

Measurements: All measurements were done on a central area of 40x40 cm within each sown micro plot, while all defoliation treatments were applied on sown plots of 60x60 cm.The first defoliation for the continuous defoliation treatment was made on 1 June 1994, as soon as plants exceeded 20cm in height. Deferred defoliation treatments

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started four weeks later on 29 June 1994. Subsequent cuttings were made at intervals of 14 days in all treatments. At each harvest, plants were cut with a hedge trimmer fitted with a catcher. Then all harvested herbage was oven-dried at 90 ^{0}C over a period of 24 h and weighed. In order to estimate the availability of herbage at each harvest occasion, and just prior to cutting, 5 plants from the buffer zone close to the border of each micro plot (including controls) were removed as whole plants (intact plants).

Medic plants were at the mature pod stage by mid November. On November 28, all residual plant material including pods were measured by harvesting to ground level in the former sampling areas of 40x40 cm within each experimental plot.Total pasture production was calculated by summing up the harvests of regrowth throughout the growing season, plus the whole plant material harvested on November 28. Analyses of variance were made on all measured and derived variables by using the program Super Anova on selected plant variables, such as forage production (kg DM/ha), forage growth rate and seed production (kg/ha), etc. The analyses of variance were carried out on herbage data from individual harvests and on cumulative data on harvested material, also on total cumulative sward production. Continuous and deferred defoliation systems were also analysed separately when a special effect was needed to be investigated in further detail. Data were transformed whenever required to stabilize the variance. Error bars on graphs refer to Standard Error of Means, unless otherwise stated.

RESULTS

Herbage Data

The summary of ANOVA on the effects of sowing rate and defoliation intensity on forage yield is presented in Table 1.

Available forage*:* There was a significant (P<0.0l) interaction between defoliation system and sowing rate across all harvests (Figure 1). The mean availability of forage in the continuous defoliation system increased significantly (P<0.0l) as sowing rate increased, but the mean availability of forage in the deferred defoliation system significantly decreased at the high sowing rate.

Available forage of the continuous defoliation system ranged from the lowest of 672 kg DM/ha (at the start of defoliation) to the highest of 6000 kg DM/ha at the end of the vegetative growth period (Figure 2). Deferred defoliation increased the availability of forage at the start of defoliation (2376 kg

Table 1. Summary of ANOVA on the effects of sowing rate and defoliation intensity on forage yield and forage components of Paraggio medic swards 1994.

Sources of variation	Forage components		
	Available forage (kg DM/ha)	Total forage production (kg DM/ha)	Forage growth rate (kg DM/ha/day)
DS[a]	*	*	NS
SR[b]	***	**	***
DI[c]	***	NS	***
DSxSR	***	***	***
DSxDI	NS	NS	NS
SRxDI	NS	NS	NS
DSxSRxDI	NS	NS	NS

[a]Defoliation system; [b]Sowing rate; [c]Defoliation intensity. NS, Not significant; *, P<0.05; ** ,P<0.01; ***,P<0.001. Interactions not mentioned were not significant.

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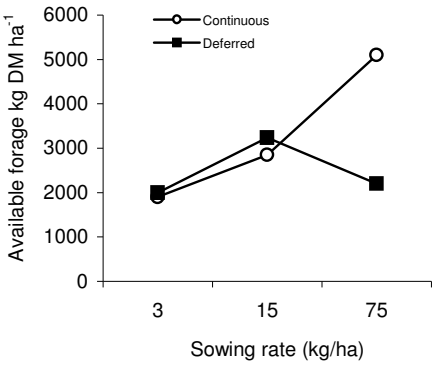

Figure 1. Interaction effect of Sowing rate and defoliation system on available forage.

DM/ha): however, due to the adverse impact of moderate (4 cm) and severe (2 cm) defoliation intensities, the mean availability of forage in this system dropped by about 1000 kg DM/ha at the second harvest. The maximum availability in this system and at the end of the growing season on September 21, 1994 was only 3375 kg DM/ha.The highest growth rate for both defoliation systems was achieved during July 27 to August 10 th which was 164 and 64 kg DM/ha/day for continuous and deferred defoliation systems respectively.

In the continuous defoliation system the availability of forage significantly increased with increasing plant density. The highest available forage was produced at high sowing rate and the lowest at the lower sowing

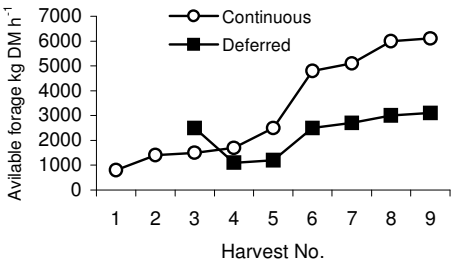

Figure 2. Interaction effect of harvest number and defoliation system on available forage across all sowing rates and defoliation intensities.

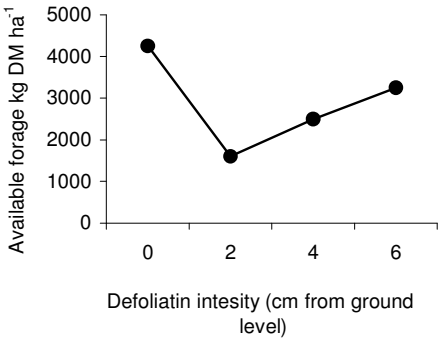

Figure 3. Effects of defoliation intensity on available forage.

rates.

In the deferred system of defoliation, high sowing rate plots throughout the growing season produced less forage than medium sowing rate and scarcely as much as the low sowing rate. Medium sowing rate was the most successful treatment with maximum available forage of 4100 kg DM/ha. The amount of available forage increased over the whole experiment period, but the increase was especially rapid in late winter and more so at the highest sowing rate.

Defoliation intensity significantly influenced ($P<0.01$) the availability of forage in both defoliation systems. The highest available forage was obtained on non-defoliated (control) plots: availability decreased as defoliation intensity increased (Figure 3).

The examination of the defoliation intensity effects at individual harvests shows no significant difference between lenient defoliation intensity and the control for the continuous defoliation system. Deferred defoliation was very sensitive to severity of defoliation. Moderate and severe defoliation intensities dramatically reduced the availability of forage (over 2000 kg DM/ha) after the first defoliation. The impact of this depression lasted for the rest of the growing season.

Total pasture production: There was a significant interaction ($P<0.001$) between defoliation system and sowing rate, which affected total forage production (Figure 4).

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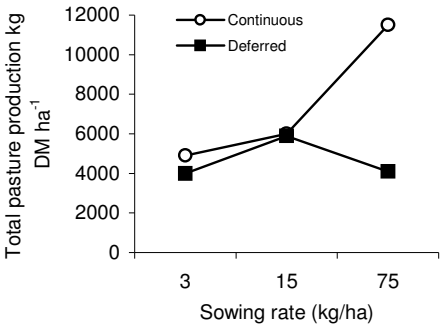

Figure 4. Interaction of sowing rate and defoliation system on total pasture production.

Under continuous defoliation mean pasture production was highest at the highest sowing rate and decreased as sowing rate decreased (11172, 6050 and 4895 kg DM/ha, respectively). At deferred defoliation the highest production was achieved at the medium sowing rate, followed by high and low sowing rates (5786, 4270 and 4025 kg DM/ha respectively). However, the effects of defoliation intensity on total forage production were not significant.

The impact of the various treatments on seed yield and seed components are summarised in Table 2.

Pod yield: Pod yield was significantly higher ($P<0.05$) with continuous defoliation than with deferred. (1152 and 967 kg/ha respectively). Defoliation very markedly reduced seed yield as compared with control. Pod yield was lowest with severe defoliation (Figure 5).

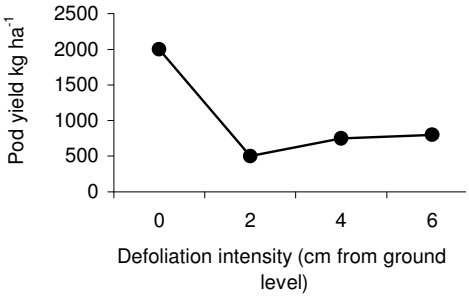

Figure 5. Effect of defoliation intensity on pod yield

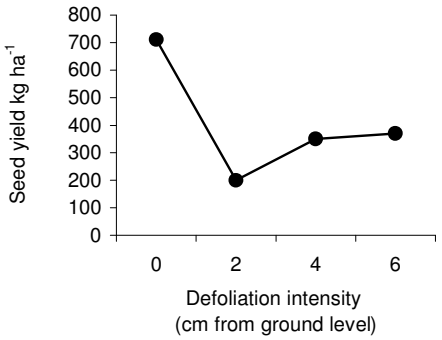

Figure 6. Effects of defoliation intensity on seed yield

Seed yield: Seed yield was significantly affected only by defoliation intensity (Figure 6). Defoliation significantly reduced seed production as compared to non-defoliated control plots (Figure 6). Defoliation to 2 cm also significantly reduced seed yields below levels of the other defoliated plots. Although the Sowing rate x Defoliation intensity interaction was not significant, Figure 7 shows that seed production was significantly reduced by deferment at the 75 kg/ha sowing rate in the undefoliated and 2 cm treatments.

DISCUSSION

Herbage Production

Available forage*:* The response to sowing rate differed in the two defoliation systems compared in this experiment. Apapers, appropriate levels of available forage are required to maintain adequate rates of both intake by livestock and regrowth of pasture.

This experiment has illustrated that the availability of pasture is determined by defoliation intensity, plant density and defoliation system (continuous or deferred). In a low density sward, lenient defoliation helped to maintain adequate availability for regrowth. However, the amount of harvested forage in this case was relatively low. In the continuous defoliation system, this problem was overcome by increasing plant density to high levels comparable to a dense, self-

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Table 2. Summary of ANOVA on the effects of defoliation system, sowing rate and defoliation intensity on seed yield and seed components of Paraggio medic pasture at Waite Institute, 1994.

Seed components	Source of variation						
	DS[d]	SR[b]	DI[C]	DSxSR	DSxDI	SRxDI	DSxSRxDI
Pod yield(kg/ha)	*	NS	***	NS	NS	NS	NS
Mean pod weight (mg)	NS	*	***	NS	NS	NS	NS
Pods (#/m^2)	*	**	***	NS	NS	*	NS
Seed yield (kg/ha)	NS	NS	***	NS	NS	NS	NS
Mean seed weight (mg)	NS	*	***	NS	NS	NS	NS
Seeds (#/pod)	NS	NS	*	NS	NS	NS	NS
Seed wt./pod wt. ratio (%)	NS	NS	NS	NS	NS	NS	NS

[a]Defoliation system; [b]Sowing rate; [c]Defoliation intensity; NS, Not significant *, P<0.05 **, P<0.01, ***, P<0.001

regenerating pasture. At this density, severe defoliation resulted in a prostrate growth habit with enough available leaf area remaining below the height of defoliation to ensure rapid regrowth. In contrast, in the deferred defoliation system, the response of pasture to the high density was a tall, self-shading sward with almost all growing points and leaf area near the top of the canopy. In this situation, severe defoliation after the period of deferment resulted in removal of almost all growing points and leaves and death of most plants. This could also happen in a high density pasture with intensive grazing after a period of deferment. Trampling by sheep would cause wastage and add to the disadvantage of this system.

During late July to early August a high pasture growth rate was seen in both defoliation systems (Figure2). The effect of high sowing rate on forage availability was outstanding at the continuous defoliation system and pasture outyielded all other treatments. The same trend was seen in the deferred defoliation system. However, no significant difference existed between low and high sowing rates in terms of pasture growth rate.

Total pasture production : The better regrowth of pasture under continuous defoliation contributed to the higher total pasture production in this system as compared to deferred defoliation. Data presented in Figure 4 show that in a continuous defoliation system plant density determines the productivity of the pasture. In a continuously grazed pasture if the defoliation intensity is to be high, it is necessary to keep the density of the pasture in a reasonably high level to ensure good pasture production.Total pasture production under deferred defoliation was more influenced by defoliation intensity than by sowing rate. High sowing rate plots in this defoliation system as well as being susceptible to inter plant competition effects and loss of smaller plants were also very susceptible to the intensity of defoliation. Severe defoliation reduced pasture production through destruction of growing points, branches and removal of photosynthetic area. Lenient defoliation ensured higher pasture production through stimulation of higher leaf area. These results are in agreement with findings reported by Donald (1954) and Ababneh (1991) who showed that, as the intensity of defoliation increased yield of shoot tissue decreased.

Seed Production

The supplementary watering employed in this experiment eliminated possible moisture stress on seed production, so the amount of seed produced was a direct response of pasture to treatments applied.

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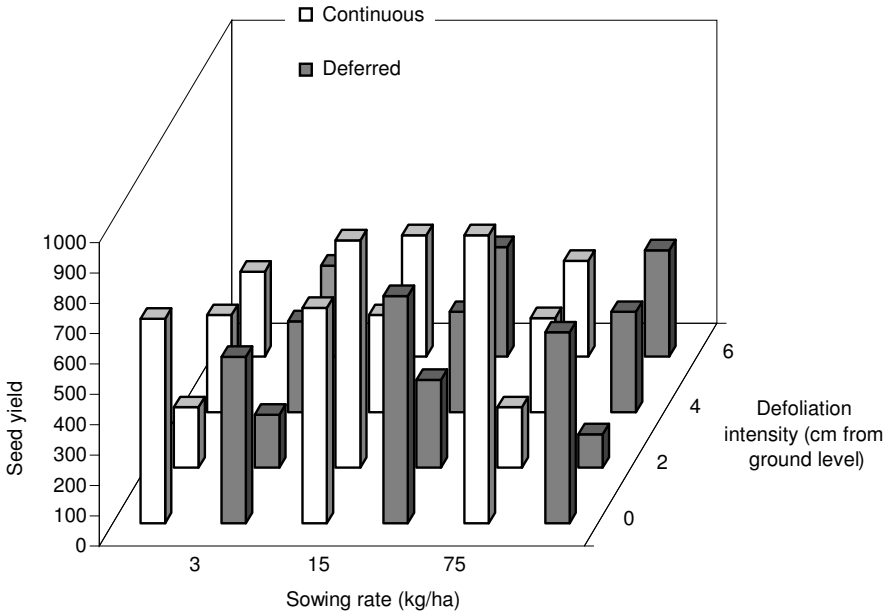

Figure 7. Effects of sowing rate and defoliation intensity on seed production at continuous and deferred defoliation.

The seed yield in annual pasture species increases with density to an optimum level and falls at high density. Williams and Vallance (1982) while growing *M. truncatula* cv. Jemalong at different sowing rates (1 to 625 kg/ha) on a sandy soil reported increases in seed yield and pod number up to sowing rates of 16 kg/ha. These findings are in agreement with results obtained in the undefoliated control of plant density of 375 seedlings/m^2 of this experiment which corresponds to 15 kg seed/ha.

The effect of defoliation intensity was more severe in deferred defoliation than continuous defoliation. Seed production reduced to 57% and 63% of the control in deferred and continuous defoliation systems respectively. The overall lower seed production in deferred defoliation system as compared to continuous system was attributed to severe reduction in seed production at high sowing rate plots under severe defoliation intensity treatment (Figure 7). Seed production in these plots reduced to 104 kg/ha as compared to control of 651 kg/ha. These results support the data of Carter (1986) who reported a dramatic reduction in seed production of medic by hay making at the early flowering. Severe defoliation intensity delayed flowering to early October (177 days after emergence) whereas control plots started flowering in early September. This was in agreement with findings of Collins and Aitken (1970) and Ababneh (1991).

Lenient and moderate defoliation intensities significantly reduced seed production compared to control plots. The results of this experiment are in accordance with data presented by Muyekho (1993) that showed that defoliation made after the start of flowering reduced seed yield through removal of the photosynthetic surfaces and production of flowers during the unfavourable weather conditions.

The destructive impact of severe defoliation intensity was more noticeable at high sowing rate in both defoliation systems. Plants at high sowing rate were slender whereas at medium and low sowing rates

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were more spaced and vigorous. Severe defoliation intensity removed a large amount of photosynthetic area at each harvest and in particular at deferred defoliation system the first harvest severely damaged the plant population through removal of most of the growing points on plants. De Koning and Carter (1987) working with subterranean clover and Muyekho (1993) with Paraggio barrel medic have reported similar results.

The common conclusion that grazing reduces seed production through the reduction in available forage is in agreement with the results obtained in this experiment and findings by Ababneh (1991) and Muyekho (1993) who applied different defoliation treatments to *Medicago truncatula* cv. Paraggio. High density pastures, severe defoliation intensity or high grazing pressure could have detrimental effects in terms of pasture recovery and seed production.

The results of this experiment showed that by far the highest seed yields were achieved from swards left undefoliated (controls). However, in a grazing system the proper utilization of pasture involves efficient use of available herbage for sheep production, as well as adequate seed yields to ensure continued, long term regeneration of the pasture. However, it is apparent that the highest seed production was not obtained from treatments giving the highest harvested forage (or highest utilization) or treatments receiving severe defoliation. This treatment reduced leaf area, flowers and pods so much that seed yield was in the vicinity of 200 kg/ha. This is the lowest level accepted as adequate to maintain seed reserves for pasture re-establishment. Almost all the' leniently or moderately defoliated swards gave seed yields higher than 200 kg/ha. This indicates that it is possible to achieve fairly high seed yields with a wide range of plant densities, moderate or lenient defoliation management, and either with or without deferment.

CONCLUSIONS

The availability of forage during the early stages of growth was encouraged by both high sowing rates and deferred defoliation. However, severe defoliation adversely affected the deferred system and reduced forage availability in this system as compared to continuous defoliation throughout the growing season. Continuous defoliation produced more cumulative forage compared to the deferred defoliation system. The higher productivity of pasture in this system was associated with pasture density and increased as density increased. Under the deferred defoliation system optimum production was obtained at medium sowing rate.

Seed production was affected by a diversity of managerial factors. Continuous and deferred defoliation across all sowing rates and defoliation intensities produced similar amounts of seed (419 and 370 kg/ha respectively).The results of this experiment show that in terms of herbage and seed production, deferment of grazing could be beneficial only if the intensity of grazing or defoliation selected do not severely damage the plant structure and photosynthetic area of the pasture during the vegetative and reproductive stages of growth.

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اثر تراکم کاشت، شدت برداشت و زمان آغاز برداشت بر روی رشد رویشی و زایشی یونجه یکساله

چکیده

برای کسب اطلاعات دقیقتر از اثر تراکم کاشت و شدت برداشت بر روی تولید علوفه و بذر یونجه یکساله رقم Paraggio در شرایط کنترل شده، این گیاه بر روی بستر برجسته (Raised bed) کشت گردید. برای مقایسه تیماریهای آزمایش از یک طرح کرتهای دوبار خرد شده در قالب بلوکهای کامل تصادفی استفاده شد. تیمارها عبارت بودند از: تیمار اول، سه تراکم کاشت شامل تراکم کم (۳ کیلوگرم بذر در هکتار)، تراکم متوسط (۱۵ کیلوگرم در هکتار) و تراکم زیاد (۷۵

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کیلوگرم درهکتار) که بر اساس بذر خالص جوانه زده به ترتیب تراکم بوته‌های ۷۵، ۳۷۵ و ۱۸۷۵ بوته در متر مربع را به وجود آورد. تیمار دوم، چهار شدت برداشت شامل: کنترل (بدون برداشت علوفه)، شدت برداشت کم (برداشت از ارتفاع ٦ سانتیمتری از سطح زمین)، برداشت متوسط (برداشت از ارتفاع ٤ سانتیمتری از سطح زمین) و شدت برداشت زیاد (برداشت از ارتفاع ۲ سانتیمتری از سطح زمین). به منظور باز سازی اثر روش چرای دام به صورت چرای ممتد و چرای تاخیری، برداشت علوفه به ترتیب از اول ماه ژوئن برای چرای ممتد و ۲۹ ماه ژوئن برای چرای تاخیری انجام شد (چهار هفته تاخیر) . بنابراین تیمارهای آزمایش عبارت بودند از : کرتهای اصلی، ۲ روش برداشت علوفه (ممتد و تاخیری) ×کرتهای خرد شده اول: سه تراکم کاشت×کرتهای دوبار خرد شده: ٤ شدت برداشت علوفه × ٤ تکرار برابر با ۹٦ کرت آزمایشی. در روش برداشت ممتد عملکرد علوفه قابل دسترس و کل عملکرد علوفه مرتع (مجموع علوفه براشت شده و باقیمانده پس از پایان آزمایش). بیشتر از روش برداشت تاخیری بود ($P<0.05$). در تراکم زیاد کاشت (۷۵ کیلوگرم بذر در هکتار) در هر دو روش برداشت علوفه (ممتد و تاخیری) عملکرد علوفه قابل دسترس و کل علوفه مرتع به طور معنی داری بیشتر از سایر تراکم های کاشت بود ($P<0.01$). شدت های برداشت متوسط و زیاد به طور معنی داری علوفه قابل دسترس و کل علوفه تولیدی مرتع را در روش برداشت تاخیری کاهش دادند ($P<0.01$). تولید بذر و اجزاء عملکرد بذر در روش برداشت ممتد نسبت به برداشت تاخیری برتری نشان دادند.

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