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The Effect of Deferred Harvesting, Sowing Density and Harvest Intensity on Forage Yield, Seed Yield and Percent Hard-seedness of Annual Medic (*Medicago scutelatta* Var Robinson)

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Abstract: To evaluate the effects of deferred harvesting, sowing density and harvest intensity on forage yield, seed yield and percent hard-seedness of annual medic (*Medicago scutelatta* Var Robinson) an experiment was conducted in Research Farm of College of Agriculture, University of Tehran, Karaj, during 2005 growing season. The experimental treatments were arranged in split-split plots based on a complete randomized block design with four replications. Were the commencement of harvesting (continuous and deferred) were allocated to main plot, the sowing density of 25, 75 and 225 plant/m^2 to split plots and the harvest intensities (different height of forage cutting from ground level) of 2, 4 and 8 cm to the split-split plots. The results indicated that the total forage (accumulated forage) production in continuous harvesting system (3624 kg ha^{-1}) was significantly more than deferred system. As the sowing density increased, forage production followed an increasing trend in this experiment. The best harvest height was 4 cm from ground level. Seed and pod yield in deferred harvesting was significantly more than continuous harvesting. As sowing density decreased and harvest intensity increased, pod yield, seed yield and percent hard-seedness followed a decreasing trend. Percent hard-seedness was 83.3 in August (during harvest of pods) which was decreased to 52.2 in March. From the economical point of the view (production costs), the continuous defoliation system at high sowing rate (225 plant #/m^2) with harvest height of 4 Cm from ground level is the best offer for farmers to produce forage and seed.

Key word: Annual medic % Deferred harvesting % Sowing density % Harvest intensity % Forage yield % Seed yield % Hard-seedness

INTRODUCTION

In annual pastures of Mediterranean-type environments, seedling density is of particular importance at the time of the autumn break in the season as early growth per unit area is directly related to plant numbers. High plant density improves herbage yield in winter and as feed scarcity in winter imposes limits on year-round animal production, high density can increase annual carrying capacity of pasture. During spring of the year there is no limit in available forage for grazing animals [1, 2]. Density influences the stage at which competition begins. Plant density is the important factor which initially determines the leaf area and dry matter production [3].

The effects of grazing on the growth of pasture plants are usually simulated by varying heights and frequencies of defoliation and the stage of growth at which defoliation occurs [4]. The success of a pasture under defoliation by grazing depends on its ability to cope and recover from continual defoliation as well as its population density during the early growing season. Since plant density has such an important influence on the productivity of medic pasture, it is necessary to include this factor in management experiments.

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 forms of cutting or artificial defoliation are necessary [5]. 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 result has been obtained by varying the frequency of defoliation, the greatest reduction in yield having occurred where the defoliations have been most frequent. Lowe and Bowler [6] suggested that lax cutting in subsequent defoliation could reduce damage from severe cutting management.

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In conclusion, defoliation has a dramatic influence on the productivity of annual legume pasture. Production differences between cultivars may be eliminated in some situation by defoliation [7]. 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 [5].

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 forage yield, seed yield and percent hard-seedness of annual medic (*Medicago scutelatta* Var Robinson).

MATERIALS AND METHODS

Site of experiment: The experiment was carried out at Agriculture Research Farm of College of Agronomy and Animal Sciences, University of Tehran, in Karaj during 2005 growing season. The site is located at 35:25 N latitude, 71:25 E longitudes with an altitude of 1321 m above the sea level. Karaj is located in about 30 km west of Tehran with a semi-arid (375mm rainfall yearly) climate. The soil of experimental site was clay loam, low in nitrogen (0.08-0.09%), low in organic matter (0.7-0.8) and alkaline in reaction with a pH of 8 and EC = 0.39 ds/m.

Planting and preparation of the experimental site: The seed of *Medicago scutelatta* var Robinson was sown on April 14, 2005, after scarification (because of hard-seedness). The area of each sub-plot was 4m^2 (2x2 m). Normal cultural practices were applied for all experimental units. The plots were hand weeded in different vegetative growing stages. Irrigation was applied at weekly intervals. Since the seed was not inoculated with proper bacteria at sowing time, enough nitrogen fertilizer of Urea (according to soil test) was applied in two growing stages (planting & 8 leaves growing stage), to stimulate the vegetative plant growth.

Design and treatments: The experimental treatments were arranged in split-split plots based on a complete randomized block design with four replications. The commencement of harvesting (continuous and deferred) were allocated to main plots, the sowing density of 25, 75 and 225 plant/m^2 to split plots and the harvest intensities (different height of forage cutting from ground level) of 2, 4 and 8 cm to the split-split plots.

Measurements: All measurements were done on a central area of 100x100 cm within each sown plot, while all defoliation treatments were applied on sown plots of 200x200 cm. A buffer zone of 100 cm was left all around each micro plot to prevent any border effects.

The first defoliation for the continuous defoliation treatment was made on 26 May 2005, as soon as plants established. Deferred defoliation treatments started two weeks later on 16 June 2005.

At each harvest, plants were cut with a hedge trimmer fitted with a catcher. To ensure defoliation at the correct height the hedge trimmer rested on a wooden frame of 2, 4 or 8 cm height.

Dry weight samples were oven-dried at 60 C to a constant weight to determine dry yield forage, available forage and growth characteristics on a dry weight basis. These were calculated by following equations:

$$CGR = (W2-W1)/(T2-T1)\ (1/S)$$

$$AF = (WP)\ (SD)$$

Where:

AF = Available forage

S = Tthe ground area on witch the dry weights have been estimated (m)

T2-T1 = Time interval between two successive harvests

W2-W1 = Total dry matter difference between two successive harvests (g)

WP = The mean weight of a plant

SD = Sowing density

Hard-seedness tests: To determine changes in hard seededness after harvesting in August and commencement next growth season (March), pods were collected from the areas of each plot which had been harvested. 25 seeds were removed at random from each plot (i.e. one group per sub-sub plot with 4 replications) giving a total of 72 samples. After brief storage in the laboratory each sample was allocated to a Petri dish and labeled. All Petri dishes contained one piece of filter paper on the bottom and one piece of filter paper on the top of the seeds. Germination tests continued for 10 days in a humidified incubator at 20 C. Germination determined the number and proportion of hard seeds.

Analyses of variance were made on all measured and derived variables using the program MSTATC. Data were transformed whenever required to stabiles the variance. Error bars on graphs refer to Standard Error of Means, unless otherwise stated.

RESULTS AND DISCUSSON

The impact of the various treatments on forage yield, pod yield, seed yield and hard-seedness are summarized in Table 1.

Total forage production: Total forage production was calculated by the sum of cumulative harvested forage. Defoliation system had a significant (P<0.001) effect on total herbage production. Continuous defoliation across all sowing rates and defoliation intensities produced significantly more forage than the deferred defoliation system.

Total forage production in Continuous defoliation was 3624.6 which was some %29 more than the deferred defoliation system. The highest mean forage yield production was achieved at high sowing rate and reduced as sowing rate decreased (5693.9, 2611.3 and 981.7 kg DM/ha, respectively). The best harvest height was 4cm from ground level. Forage yield in 4cm harvest height was 29.1% and 37.3% more than harvest height of 2 and 8 Cm, respectively.

There was a significant interaction (P<0.001) between defoliation system and sowing rate which affected total forage production (Fig. 1). Under continuous and deferred defoliation the highest mean pasture forage was achieved at high sowing rate and reduced as sowing rate decreased (Fig. 1).

Defoliation system x Defoliation intensity interaction was significant (P<0.001) on forage yield. The maximum forage yield was obtained from Continuous defoliation system and harvest height of 4 Cm from ground level while the minimum forage yield was obtained from deferred defoliation system and harvest height of 8 Cm from ground level (Fig. 2).

Table 1: Summary of ANOVA on the effects of defoliation system, sowing rate and defoliation intensity on forage yield, pod yield, seed yield and hard-seedness of *Medicago scutellata*

	Source of variation						
Plant characteristics	DS‡	SR†	DI+	DSxSR	DSxDI	SrxDI	DsxSRxDI
Forage yield (kg DM/ha)	***	***	***	***	***	***	***
Pod yield (kg DM/ha)	NS	***	***	NS	NS	***	NS
Seed yield (kg DM/ha)	*	***	***	NS	*	***	*
Percent hard-seedness	NS	***	***	NS	NS	***	NS

NS: Not significant* P<0.05 ** P<0.01 ***P<0.001

‡DS: Defoliation System †SR: Sowing Rate +DI: Defoliation Intensity

There was a significant (P<0.001) interaction between sowing rate and defoliation intensity. The maximum forage yield was obtained from the highest sowing density and harvest height of 4 Cm from ground level. In contrast, in low sowing density and harvest height of 2 Cm from ground level, the minimum forage yield was obtained (Fig. 3).

The Defoliation system x Defoliation intensity x Sowing Rate interaction was significant (P<0.001). The forage yield production in Continuous defoliation system, 225 plant #/m^2 and harvest height of 4 Cm from ground level was maximum. In contrast the minimum forage production obtained from Differed defoliation system, 25 plant #/m^2 and harvest height of 8 Cm from ground level (Fig. 4).

As the sowing density increased, forage production followed an increasing trend in this experiment. Severe defoliation intensity (2 cm height) beside Moderate defoliation intensity (4 cm heights) lessened strength of plant for production of dry matter because in this defoliation intensity plant forfeited a lot of leaf in embryonic stages of living.

Continuous defoliation produced more cumulative forage compared to the deferred defoliation system. The better regrowth of pasture under Continuous defoliation contributed to the higher available forage in this system as compared to deferred defoliation [8]. Positive and significant correlations existed between CGR and total forage production (R^2 = 0.989)***. This correlations is consistent with this result (Fig. 5).

Severe defoliation intensity reduced pasture production through destruction of growing points, branches and removal of photosynthetic area. Lenient defoliation intensity ensured a higher pasture production through stimulation of higher leaf area. These results are in agreement with findings reported by Donald [9] and Ababneh [10] who showed that as the intensity of defoliation increased yield of shoot tissue decreased.

Pod yield: Defoliation system did not significantly affect yield pod. Sowing rate significantly (P<0.05) affected the yield pod (Table 1). The impact of low sowing rate was severe and reduced the yield pod by 75% compared to high sowing rate. Defoliation very markedly reduced pod yield compared with control. Pod yield was lowest with severe defoliation. There was a significant (P<0.001) interaction between sowing rate and defoliation intensity.

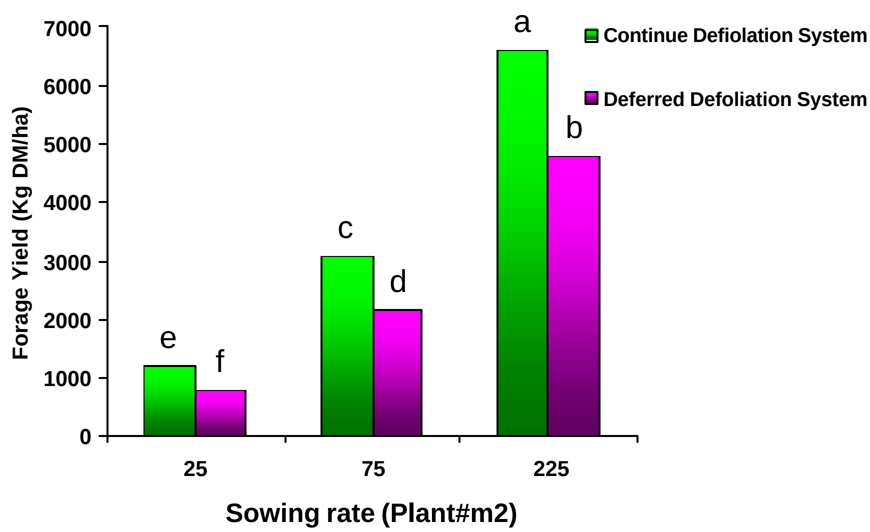

Fig. 1: Interaction of sowing rate and defoliation system on total forage production

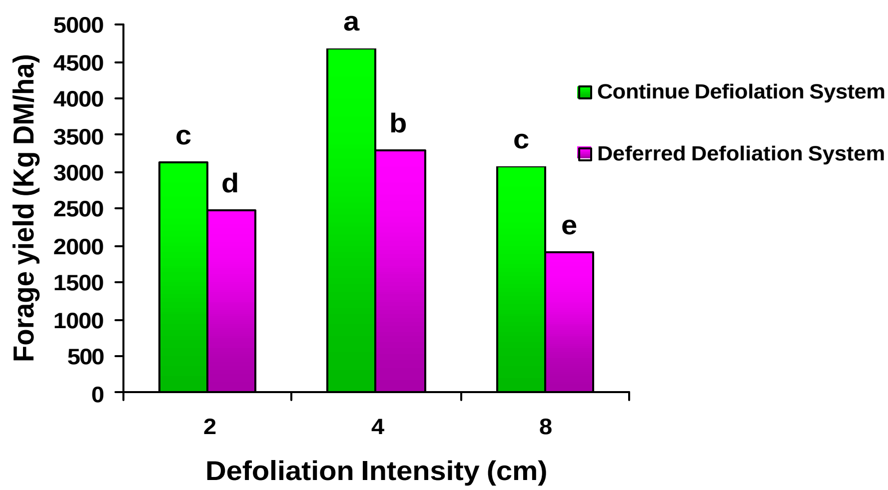

Fig. 2: Interaction of defoliation intensity and defoliation system on total forage production

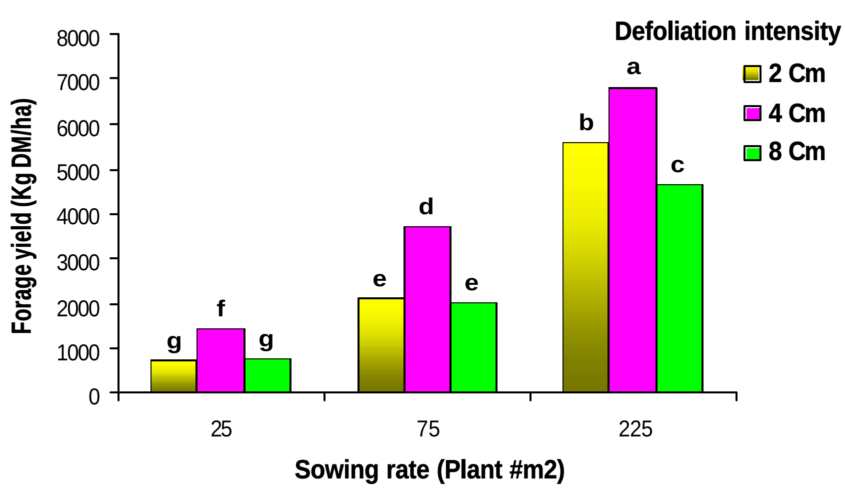

Fig. 3: Interaction of defoliation intensity and sowing rate on total forage production

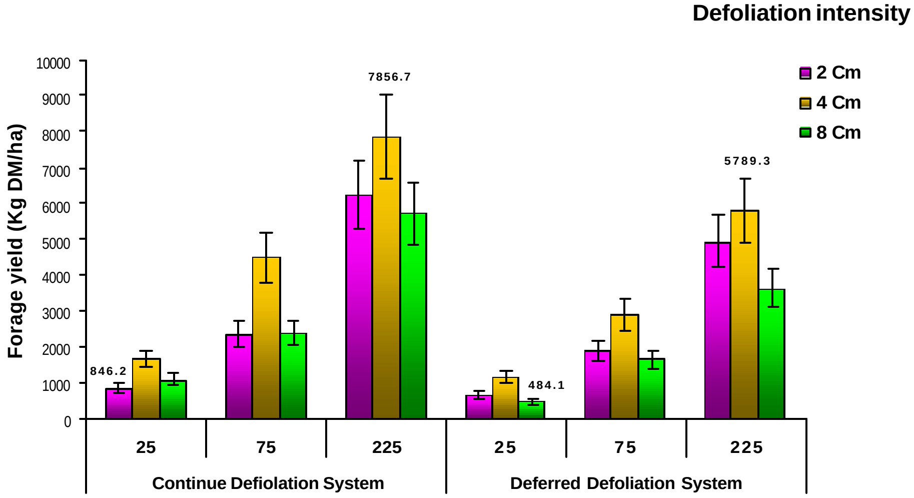

Fig. 4: Interaction of defoliation intensity, sowing rate and defoliation system on total forage production

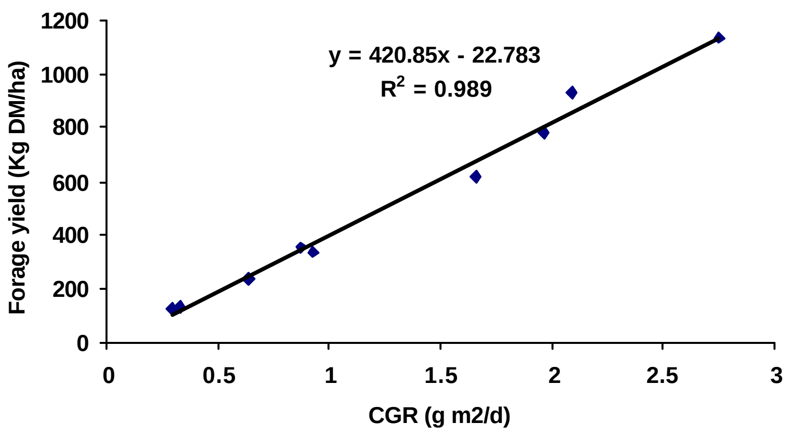

Fig. 5: Correlation between Crop Growth Rate (CGR) and total forage production

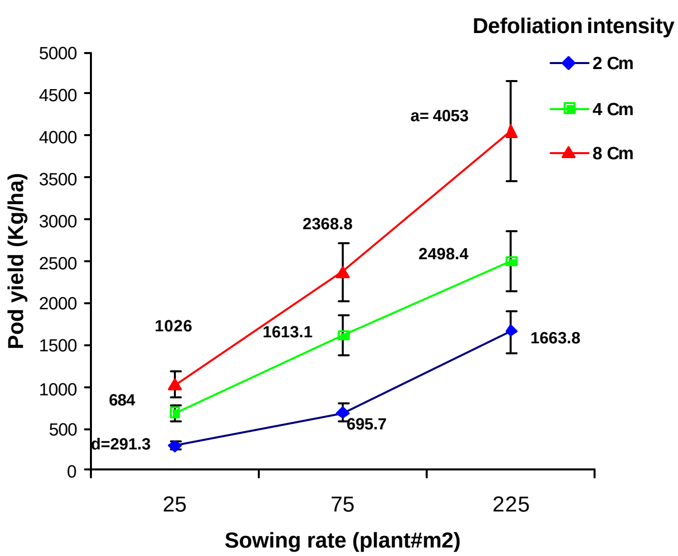

Fig. 6: Interaction of defoliation intensity and sowing rate on pod yield

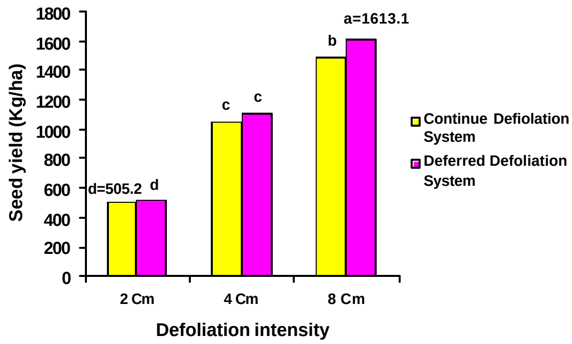

Fig. 7: Interaction of defoliation intensity and defoliation system on seed yield

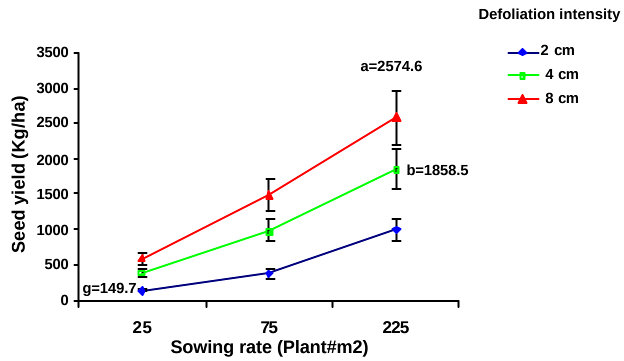

Fig. 8: Interaction of defoliation intensity and sowing rate on seed yield

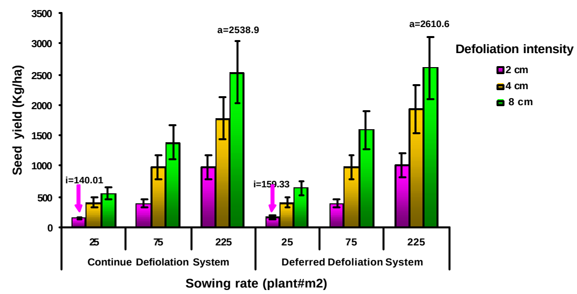

Fig. 9: Interaction of defoliation intensity, sowing rate and defoliation system on seed yield

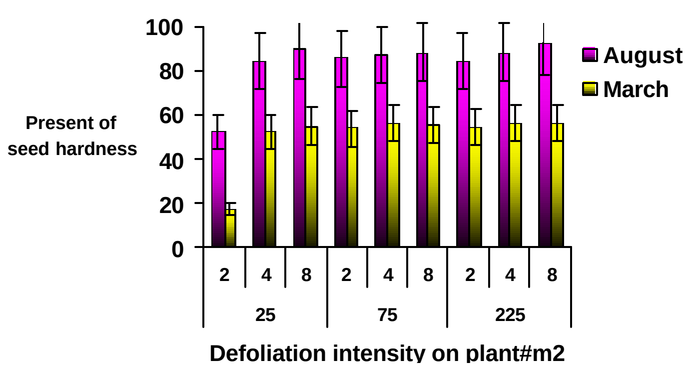

Fig. 10: Interaction of defoliation intensity and sowing rate on percent of hard-seededness in August and March 2005

The maximum pod yield was obtained from highest sowing density and harvest height of 8 Cm from ground level. In contrast, in low sowing density and harvest height of 2 Cm from ground level the minimum pod yield was obtained (Fig. 6).

Seed yield: System of defoliation had a significant (P<0.01) impact on seed yield. Seed yield under deferred defoliation was %6 more than continuous defoliation. The highest mean seed yield production was achieved at high sowing rate and reduced as sowing rate decreased (380.4, 1812.6 and 951 kg/ha, respectively). The best harvest height was 8 cm from ground level and reduced as harvest height decreased (1551, 1081 and 512 kg haG^{1}, respectively).

Defoliation system x Defoliation intensity interaction was significant (P<0.05) on seed yield. The maximum seed yield was obtained from deferred defoliation system and harvest height of 8Cm from ground level. However, the minimum forage yield was obtained from Continuous defoliation system and harvest height of 2 Cm from ground level (Fig. 7).

There was a significant (P<0.001) interaction between sowing rate and defoliation intensity. The maximum seed yield was obtained from highest sowing density and harvest height of 8 Cm from ground level. In contrast, in low sowing density and harvest height of 2 Cm from ground level, the minimum seed yield was obtained (Fig. 8).

The Defoliation system x Defoliation intensity x Sowing Rate interaction was significant (P<0.05). The seed yield in Continuous defoliation system, 25 plant #/m^2 and harvest height of 2 Cm from ground level was minimum. In contrast, the maximum seed yield was obtained from Deferred defoliation system, 225 plant #/m^2 and harvest height of 8 Cm from ground level (Fig. 9).

Seed yield was significantly higher (P<0.01) with deferred defoliation than with continuous defoliation (1152 and 967 kg haG^{1}, respectively). Despite the findings of Muir *et al*. [11], defoliation intensity very markedly reduced seed yield compared with control. Seed yield was lowest with severe defoliation.

As sowing density decreased and harvest intensity increased, pod yield and seed yield followed a decreasing trend. Williams and Vallance [12] while growing *M. truncatula* cv. Jemalong at different sowing rates (1 to 625 kg haG^{1}) on a sandy soil reported increases in seed yield and pod number up to sowing rates of 16 kg haG^{1}. Cocks [13] reported that *M. nonea* sown at densities of 10 and 200 kg haG^{1} produced the highest seed yield at densities of 200 kg haG^{1}.

The higher pod yield and seed production at high sowing rate were attributable to differences in the individual plant characteristics as affected by different growth habits imposed by sowing rates. At low sowing rate many growing points (nodes), racemes and flowers per plant were initiated because of less competition among the plants but this did not compensate for fewer plants per m^2 in producing yield per unit area. At maximum sowing rate the inter-plant competition reduced the number of flowers developed, but this reduced number of flowers was within the capacity of plants to support through to seed production. The high number of flowers per plant at high sowing rate together with the number of plants per m^2 resulted in a large number of pods which gave the highest seed yield/ha.

The lower number of pods produced in defoliated plots could be explained by removal of flowers and flowering nodes with defoliation [14]. The significant reduction in seed yield in severe defoliation compared to lenient and moderate defoliation intensities was mainly due to lower mean pod weight and lower numbers of pods produced per m^2 in this treatment [15]. This could be attributed to severe removal of flowering sites, existing flowers and poorer recovery in vegetative growth than in the lenient defoliation plots.

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. Similar results have been reported by de Koning and Carter [16] working with subterranean clover and Muyekho [14] with Paraggio barrel medic.

Percent hard-seedness: There was a significant (P<0.001) interaction between sowing rate and defoliation intensity on Percent hard-seedness. As sowing density decreased and harvest intensity increased, percent hard-seedness followed a decreasing trend (Fig. 10).

In this experiment minimum hard-seedness was obtained at lowest sowing density. Percent hard-seedness in plots with 25 plant/m^2 compared to other plots, decreased about %24 in March. As harvest intensity increased percent hard-seedness followed a decreasing trend. The minimum hard-seedness was obtained from the highest harvest intensity. In contrast, in harvest heights of 4 and 8 Cm from ground level, the maximum percent of hard-seedness was obtained.

The percent hard seed at lowest sowing rate and highest defoliation intensity was minimum in August (during harvest of pods) and March. The seed production is lowest in this treatment and that is why the pasture tries to survive in next year by producing a more proportion of soft seeds [15]. The results of this experiment supports the findings of Quigley and Carter [17] which demonstrated removal of residues increased the exposure of the pods to fluctuating temperatures under more severe defoliation. Agronomic condition at growing season affects more than environmental condition on hard-seedness after pods are harvested. This is in agreement with the results obtained by Taylor [18].

Time of the exposure of the pods to fluctuating temperatures influenced the rate of breakdown of seed coat permeability resulting in reduced hard-seededness. The percent of hard-seedness was 83.3 in August (during harvest of pods) which decreased to 52.2 in March. This was in agreement with findings of Shabani [19]. Berayam and Smith [20] studied on 4 culivars of annual medic and demonstrated that the proportion of soft seed was less than 5% in summer which increased to 35% at the commencement of raining season in autumn.

CONCLUSIONS

The results of this experiment showed that the maximum forage yield was in obtained from Continuous defoliation system, 225 plants #/m^2 and harvest height of 4 Cm from ground level. This treatment was considered as the best treatment to produce forage.

Maximum seed yield was obtained from Deferred defoliation system, 225 plant #/m^2 and harvest height of 8 Cm from ground level. Seed yield at treatment with 25 plant #/m2 (lowest sowing rate) at all harvest intensities and defoliation systems did not produce enough seed to encourage seed bank for regeneration in the forth coming years.

Seed production in both defoliation systems at medium (75 plant #/m2) and high sowing rates (225 plant #/m2) and harvest heights of 4 and 8 Cm from ground level was more than 1000 Kg/h. Because of hard seed break down trend about %50 of this seed are able to germinate in the next year (March). This amount is sufficient to encourage seed bank reserve for future regenerations.

Continuous defoliation was better than deferred defoliation system because of more forage production at the beginning of grazing season. As sowing density increased, pod yield, seed yield and forage yield followed an increasing trend. Production of forage and seed in medium and high sowing rates were appropriate. From the economical point of the view (production costs), the continuous defoliation system at high sowing rate (225 plant #/m^2) with harvest height of 4 Cm from ground level is the best offer for farmers to produce forage and seed. More research on this topic with grazing livestock is recommended.

REFERENCES

1. Carter, E.D., 1987. Establishment and natural regeneration of annual pastures. In Temperate Pastures: Their Production. Use and Management.
2. Carter, E.D., 1982. The need for change in maintaining the best use of medics in the cereal-livestock farming systems of South Australia. Proc. 2nd. Aust. Agron. Conf. Wagga Wagga. NSW. pp: 180.
3. Spedding, C.R.W., 1971. Grassland Ecology. Oxford Univ., Press, Oxford, pp: 221.
4. Motazedian, I., 1984. Effect of defoliation treatments on forage quality, quantity and species composition of *Lolium prenne* L. *Trifolium subterraneum* L. pasture Diss. Abstr. Intl. B., 44: 2966.
5. Carter, E.D., 1989. The production and management of pastures based on annual medics and clovers. Pasture Symposium. The University of Adelaide. Waite Agricultural Research Institute. Charles Hawker Conference Centre- Feb. 15, pp: 1- 12.
6. Lowe, K.F. and T.M. Bowdler, 1980. Effect of seeding rate and nitrogen on the herbage production of rain-grown and irrigated oats in sub-coastal south-eastern Queensland. Qld. J. Agric. Anim. Sci., 37: 145-154.
7. Collins, W.J., I. Rhodes, R.C. Rossiter and M.J. Palmer, 1983. The effect of defoliation on seed yield of two strains of subterranean clover grown in monocultures and in binary mixtures. Aust. J. Agric. Res., 34: 671-679.
8. Chaichi, M.R. and P.G. Tow, 2000a. Effect of stocking density and grazing period on herbage and seed production of paraggio medic. J. Agric. Sci. Technol., 2: 271-279.
9. Donald, C.M., 1954. Competition among pasture plants. II. The influence of density on flowering and seed production in annual pasture plants. Aust. J. Agric. Res., 5: 585-597.
10. Ababneh, M.H., 1991. The ecology and productivity of annual medic genotypes. Ph.D. Thesis. The University of Adelaide, Australia, pp: 265.

11. Muir, J.P., W.R. Ocumpaugh and T.J. Butler, 2005. Trade-offs in forage and seed parameters of annual medicago and trifolium species in North-Central Texas as affected by harvest intensity. Agron. J., 97: 118-124.
12. Williams, C.M.J. and N.A. Vallance, 1982. New medic pasture systems to increase production in pasture/cereal rotations in the Victorian Mallee. Proc. 2nd. Aust. Agron. Conf. Wagga Wagga, pp: 317.
13. Cocks, P.S., 1990a. Dynamics of flower and pod production in annual medics (*Medicago* spp.). 1. In spaced plants. Aust. J. Agric. Res., 41: 911-921.
14. Muyekho, F.J.N., 1993. Environmental and agronomic factors affecting seed production in annual medics. Ph.D. Thesis. The University of Adelaide. pp: 232.
15. Chaichi, M.R., E.D. Carter and P.G. Tow, 1996b. Impact of stocking densityand duration in spring on medic growth and delopment. South Australia. Proceedings of the 8th Australian Agronomy Conference. Toowoomba, queensland, Australia. Australian Society of Agronomy Inc: 132-135.
16. de Koning, C.T. and E.D. Carter, 1987. Impact of grazing by sheep on subterranean clover cultivars. Proc. 4th Aust. Agron. Conf. Melbourne, pp: 169.
17. Quigley, P.E. and E.D. Carter, 1989. The effects of straw mulch on establishment of annual medics. Proc. 5th. Agron. Conf. Perth. September 1989, pp: 588.
18. Taylor, G.B., 1996. Effect of the environment in which seeds are grown and softened on the incidence of autumn seed softening in two species of annual medics. Aus. J. Agric. Res., 47(1): 141-159.
19. Shabani, G. and M.R. Chaichi,, 2004. Climate, time and storage condition effects on the rate of hardseed breakdown of *Medicago scutellata* cv. Robinson. J. Pajouhesh & Sazandegi, 62: 91.
20. Brahim, K. and S. Smith, 1993. Annual medic establishment, potential and persistence in southern Arizona. J. Range Management, 42: 21-25.