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Study of productivity pattern over 3 years of some annual grass and legume fodders carried as pure and as mixture in rainfed cereal based system in Algerian semiarid area

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Abstract. In the aim to improve sustainability and resilience of fallow-wheat system highly vulnerable against climatic change (REFORMA Arimnet project), over the years 2012/2013, 2013/2014 and 2014/2015, 1 triticale, 1 oat (grass), 2 peas (tall and semi-dwarf), 1 common vetch and 1 Narbonne vetch varieties have been tested in a device mimicking a fodder - wheat rotation in a rainfed system. Elementary experimental plots of 12 m^2 each (6 pure, 8 doubles and 2 complexes) are divided into 4 blocks. The wheat is sown on a plot similar to that of the set of all fodder plots within each block. The measurements concerns dry biomass productivity and botanical composition. Results vary depending on weather conditions, particularly the rainfall total amount and its seasonal distribution. The spring rains appear having decisive effect on productivity whatever the annual amounts received. Productivity of hay appears higher in grasses relative to the legumes in pure, with an advantage for oats. Among legumes, erect pea distinguished itself by an interesting and somewhat fluctuating productivity during the years while the common vetch and Narbonne vetch recorded low results. Binary associations showed better yields than complex. In each of the two combinations, those containing triticale gave the best yields while combinations containing oats have experienced lower productivity but showed a better balance regarding the botanical composition. Wheat yields were variable and generally follow the amount of rain received. On the whole, it appears that the farms practicing this system can replace the nude fallow by a rainfed pure or association fodder culture which will strengthen their livelihoods and sustainability by fighting against soil erosion.

Keywords. Legumes – Grasses – Fodder associations – Productivity – Phenology – Algeria – Semi-arid.

Comportement et performances pendant 3 années de certains cultivars fourragers menés en pur et en association dans un système céréalier pluvial en zone semi-aride algérienne

Résumé. *Dans le but d'améliorer la durabilité et la résilience des systèmes céréaliers-jachère face aux changements climatiques (projet REFORMA – ARIMNET), au cours des années 2012/2013, 2013/2014 et 2014/2015, une variété de triticale, une d'avoine (graminées), 2 de pois, une de vesce commune et une de vesce de Narbonne ont été mises en expérimentation dans un dispositif mimant une rotation au sein d'un système blé-fourrages mené en pluvial. Les parcelles élémentaires expérimentales de 12m2 chacune sont réparties en 4 blocs (6 en pur, 8 en doubles et 2 complexes). Le blé est semé sur une parcelle équivalente à celle de l'ensemble de toutes les parcelles de fourrages dans chaque bloc. Les mesures effectuées concernent la productivité en biomasse sèche et la composition botanique. Les résultats varient en fonction des conditions climatiques notamment la quantité de pluie et sa répartition saisonnière. Les pluies printanières apparaissent à cet effet déterminantes quelles que soient les quantités annuelles reçues. La productivité en foin est plus élevée chez les graminées relativement aux légumineuses semées en pur, avec un avantage pour l'avoine. Chez les légumineuses, le pois fourrager érigé s'est distingué par une productivité intéressante et peu fluctuante durant les années alors que la vesce commune et la vesce de Narbonne ont enregistré des résultats plus faibles. Les associations binaires ont enregistré de meilleurs rendements que les complexes. Dans chacune des combinaisons, celles contenant le triticale ont donné les meilleurs rendements alors que les associations contenant l'avoine ont enregistré une productivité plus faible mais elles ont montré un meilleur équilibre en ce qui concerne la composition botanique. Les rendements de blé ont été variables et suivent globalement la quantité de pluie reçue. D'une manière globale, il apparaît que les exploitations pratiquant ce système peuvent remplacer la jachère nue par une*

culture fourragère en pur ou en association qui renforcera leurs sources de revenus et la durabilité de leur système tout en luttant contre l'érosion des sols.

Mots-clés. *Légumineuses – Graminées – Associations fourragères – Productivité – Phénologie – Algérie – Semi-aride.*

I – Introduction

Semi-arid rainfed cereal – livestock systems are very widespread in Algeria (30 % of the agrarian area) and constitute the productive base of the major part of the cereal sector (80%). The small average of farm size (< 8 ha) and natural unfavorable conditions (shallow soils, high erosion risks) are the traits of a certain vulnerability of these systems. These one are threatened than by a marked insufficiency of high-protein feedstuff, the overexploitation of pastoral resources, the increasing costs and/or the decreasing availability of irrigation water and mineral fertilizers, and the increasing drought and heat stress arising from climate change. Natural feeding resources are unable to satisfy the growing needs of livestock following the deterioration of grazing lands. In the past, large farms found free of charge feeding resources (fallow, meadows, rangelands), but with reducing farm size, farms are abandoning pastoral sheep more exigent on large natural pastures and are developing progressively bovine on rainfed or/and irrigated fodder productions (Abbas, 2013). The diversification of fodder production possibilities on rainfed conditions such as forage legumes and legumes / grasses associations could be of a paramount importance for stakeholders (Abdelguerfi, 1976). Among arable forage legumes in cereal semi -arid zones of Algeria the genus *Pisum* (peas) could constitute a base of sustainable fodder systems well adapted and integrated into cereal rotations. Grown on fallow in pure stand and / or in combination with one or more annual grasses forages could provide an abundant and of excellent quality hay (Rihawy *et al,* 1987). To test efficiency of such forages, this paper gives the results of 3 successive years in the semi-arid region of Sétif (Algeria).

II – Material and methods

The experiment was carried out in 2012-2013, 2012-2013 and 2014-2015 at Sétif INRAA station (36° 9'26.30"N, 5°22'17.78"E, and altitude: 970m). In 2011/2012, land was driven as fallow. Trials were put in rotation with wheat. The soil was clay-loam with low organic matter, a total rate of 35% limestone and pH 7.2. The soil tillage was light and consisted in 3 passages of cover-crop machinery. Seeding was made on October 27, 2012 and mowing on May, according to the physiological stages of each culture. Weather conditions were close to the typical climate of the region: mild and dry autumn, cold and somewhat rainy winter, wet spring, hot and dry summer. Forage resources used are shown in Table 1.

Table 1. Characteristics of crop material used

Crop material	Species	Varieties	Origin	Observation
Triticale	*Tritical secal*	Amarillo	CRA/ FLC (Italy)	
Common oat	*Avena sativa*	Genziana	CRA/ FLC (Italy)	
Pea 1 (P1)	*Pisum sativum*	Kaspa	CRA/ FLC (Italy)	Semi-dwarf
Pea 2 (P2)	*Pisum sativum*	*Linea* 1-27b	CRA/ FLC (Italy)	tall
Common vetch	*Vicia sativa*	*Barril*	CRA/ FLC (Italy)	
Narbon vetch	*Vicia narbonensis*	Bozdag	Turkey	

The experimental design consisted in a completely randomized block design (blocks). Each block contained elementary plots of 4 X 3 m (12 m^2) for each experimental crop grown in pure stand and each mixture between 2 fodders (one grass and one legume) and 4 fodders (2 legumes and 2 grasses). The number of elementary crop variants was 64 (16 X4). Seeding was made manually in lines spaced 25 cm with doses presented in Table 2.

Table 2. Seed doses employed (kg/ha)

Crop material	Pure stand	Binary mixture (pure stand/2)	Complex mixture (pure stand/4)
Kaspa (P1)	168.73	84.37	42.18
Linea 1/27/b (P2)	159.16	79.58	39.79
Narbon vetch (N)	144.90	72.45	36.23
Common vetch (V)	81.05	40.53	20.27
Oat (O)	91.37	45.68	22.84
Triticale (T)	103.16	51.58	25.79

Grasses were fertilized with 160 kg N ha^{-1} while the pure legumes or associations profited from 50 kg N ha^{-1}. The pure grasses received 50% nitrogen fertilizer at planting and the rest at tillering. Phosphorus fertilisation was 120 kg P/ha for pure grasses and 300 kg P/ha for legumes in pure stand and in association. Mowing was performed manually on the entire surface of each plot. Cuts were done at following stages: waxy pods for legumes and early heading for grasses. Fresh weight was assessed on site and the dry weight was obtained after oven-drying (65 °C for 72 h) a sample of 200 g of each micro plot. A sample corresponding to the yield of 1 m^2 was used for determining the rate of the different botanical components. Statistical analysis was performed by XLSTAT ® software. Temperatures and rainfall were very variable between months and years. Winter was very cold and received the most rainfall (when crops did not need). In the spring, when the vegetation was in optimal growth, rainfall decreased and temperatures increased quickly. Differences between years were in favour of the two first years (respectively 422 and 407mm against 360mm between September and June). The third one had a very cold winter and dry autumn and spring. First year was more rainy but at final plant cycle, dryness occurred strongly.

III – Results and discussion

Year had a significant effect on dry biomass production (Table 3). **Pure legumes**: DM yields increased progressively to reach more than 6 t.ha^{-1} in 2015 especially peas and common vetch. Both tall and semi-dwarf pea cultivars seemed more adapted regarding this parameter. Narbon vetch showed a significantly lower yield (< 4 t.ha^{-1}). **Pure grasses**: oats and triticale gave very close productions, around 8 t ha^{-1}. First year production was probably affected by the rainfall deficit in late spring. **Binary mixtures**: in most combinations, it was observed an increase of productivity over time, despite the weather variability. The positive effect of wheat legume/mixtures rotation (soil nitrogen fertility) could be the main factor of these results. Pea's mixtures with triticale and/or with oat were the well performing. Common vetch gave also acceptable results with the 2 tested grasses. Narbon vetch did not give, however, satisfactory results. Complex mixtures showed less importance relatively to binary mixture. In the 2 last years Narbon and common vetches seemed more efficient than peas unlike pure and grasses binary mixtures. Wheat production was significantly increasing over the experiment period (1.1, 1.55 and 2.65 t.ha^{-1}) confirming the well effect of this rotation on whole system productivity.

The weeds rate was very variable. Its amount was in average rather important, around 30% of the total dry biomass. The experiment land long fallow use (3 successive years) could explain this situation. On the other hand, we assisted to a progressive decrease of weed infestation,

except in grasses and complex mixtures. Bromine gender was very important especially with wheat. More fallow resorption by fodders could certainly reduce weed amounts. Legume's rate in mixtures varied significantly between the first and the second year. It seemed to be stabilized among the second and the third year. It reached around 35% in average. This result was not optimal but could progress positively over time. Legume cultivars used could be less resistant than grasses to extreme weather conditions like frosts and snow occurring every year in winter and early spring. This phenomenon could explain losses in legumes. Peas with triticale registered the best rates (close to 40%). Oat cultivar was more aggressive against the used legumes. Narbon vetch did not give satisfactory results in mixtures. Legume's rate in complex mixtures showed a positive evolution reaching more than 40 %. The two pea cultivars were more adapted than vetches. The outcomes of the trials were very close to those obtained in Tunisia, Greece and Turkey in humid conditions (Hechmi, 1999; Lithourgidis *et al.*, 2011; Yilmaz *et al.*, 2015).

Table 3. Productivity parameters of the different tested crops (O: oat, T: triticale, P1: tall pea, P2: semi dwarf pea, V: common vetch, N: Narbon vetch, In bold significant high an low values)

	Total DM yield (t/ha)			**Weeds free total yield (t/ha)**			**Legumes % of total yield**			**Weeds % of total yield**		
Crops	**2012/ 2013**	**2013/ 2014**	**2014/ 2015**	**2012/ 1013**	**2013/ 2014**	**2014/ 2015**	**2012/ 2013**	**2013/ 2014**	**2014/ 2015**	**2012/ 2013**	**2013/ 2014**	**2014/ 2015**
N	**2.02**	**2.83**	**3.82**	0.90	2.00	2.16	100.0	70.67	56.54	55.55	29.33	43.46
NO	4.27	5.73	5.97	2.45	3.28	3.96	0.05	**20.94**	23.63	**42.78**	**42.77**	33.76
NT	3.98	**8.42**	3.88	2.14	4.53	2.92	0.07	**17.42**	15.56	**46.17**	**46.17**	24.71
NVOT	3.00	**7.65**	**7.14**	1.98	**5.90**	4.44	0.05	19.07	43.40	34.02	22.86	37.84
O	4.53	**8.38**	**8.91**	3.86	**6.43**	**5.66**	0.00	0.00	0.00	14.85	23.25	36.52
P1	2.72	3.79	**7.16**	2.14	3.13	4.15	100.0	82.70	58.03	21.33	17.30	**41.98**
P1 O	3.47	7.39	6.63	2.36	5.04	4.45	0.10	35.96	25.63	31.85	31.85	32.92
P1 T	2.10	7.12	6.13	1.42	4.50	4.12	0.08	30.03	28.56	32.56	36.82	32.70
P1P2OT	4.86	6.47	6.61	3.07	5.44	4.41	0.12	27.46	61.37	**36.82**	15.94	33.34
P2	3.69	4.09	**6.97**	2.61	3.76	4.29	100.0	91.91	61.59	29.32	8.09	**38.41**
P2 O	3.45	**6.69**	**8.22**	2.44	4.73	**5.64**	100.0	33.12	34.82	29.34	29.34	31.45
P2 T	4.30	**6.66**	**9.02**	2.80	4.34	**5.69**	0.15	31.58	39.77	34.84	34.84	36.88
T	3.81	**8.69**	**7.54**	3.35	**7.14**	4.93	0.00	0.00	0.00	12.11	17.78	34.59
V	2.02	4.16	6.50	0.90	3.60	3.91	100.0	86.65	60.11	100.0	13.35	39.89
VO	4.63	6.63	7.05	2.86	4.09	4.46	0.03	30.83	21.70	**38.25**	38.26	36.73
VT	3.11	8.05	5.92	1.95	5.05	3.91	0.05	30.75	27.62	**37.28**	37.28	33.96

IV – Conclusions

Narbon vetch was clearly confirmed as inappropriate for mixtures and the cultivar tested was not adapted as pure stand crop. Tall and semi-tall peas tested cultivars gave interesting results and could be included as part of sustainable strategies of fallow in cereal based semiarid areas. Triticale showed good values and could be also another part of this strategy with oats.

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