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Yielding ability of different annual cereal-legume mixtures

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Abstract. The preliminary results of a trial aimed at optimizing legume-cereal mixtures are reported. The experiment was carried out during the season 2012-2013 in North Sardinia (Italy). Sixteen plots were sown in November 2012 with pea or vetch and oat or triticale in monoculture and mixtures, following a randomized complete block design with 4 replicates. Measurements included dry matter production, botanical composition and phenology. The dry matter production of sown species ranged between 5.0 and 7.3 t ha^{-1}. Both vetches cultivars showed a very competitive behaviour against unsown species. These preliminary results allowed to identify some mixtures with correct dry matter yield combined with a favourable forage composition and a satisfactory control of unsown species.

Keywords. Annual forage crops – Pea-based mixtures – Binary mixtures – Grass pea – Common vetch.

Capacité de production de divers mélanges annuels de céréales et de légumineuses

Resumé. *Les premiers résultats d'une expérimentation dont l'objectif était d'optimiser des mélanges de céréales et de légumineuses sont présentés. Seize parcelles ont été semées en Novembre 2012 avec pois ou vesce et avoine ou triticale, en monocultures et en mélanges, selon un plan expérimental randomisé avec 3 répétitions. Des mesures ont été effectuées sur la biomasse : mesure de la production de matière sèche, analyse de la composition botanique et de la phénologie. La production de matière sèche des espèces cultivées variait entre 5,0 et 7,3 t ha^{-1}. Les deux cultivars de vesce ont montré un haut niveau de compétitivité par rapport aux espèces non semées. Ces résultats préliminaires ont permis d'identifier des mélanges avec un bon rendement combiné à une composition favorable du fourrage et un contrôle satisfaisant des espèces sauvages.*

Mots-clés. *Cultures fourragères annuelles – Mélanges à base de pois – Mélanges binaires – Vesce de Narbonne – Vesce commune.*

I – Introduction

Crop-livestock systems are threatened by the overexploitation of forage resources, the marked insufficiency of high-protein feedstuff, the increasing costs of agricultural inputs and climate change. Enhancing forage productivity by exploiting synergies among different functional groups of plants as an alternative to high artificial inputs is one of the challenges faced by agricultural research (Finn *et al.,* 2013). Legumes and cereals mixtures are of particular interest to boost fodder protein content especially in organic farming systems, where the self-sufficiency in protein production allows a higher economic profitability. Nonetheless, the success of the mixtures relies on the right choice of species and varieties, as they could have a facilitative effect one each other, produce maximum yield at the same harvest time, and have the same sowing date (Eskandari *et al*., 2009).

The objective of our experiment was to optimize the composition of annual pea-based mixtures according to the associated cereal (oat or triticale) and the pea plant type (semi-dwarf semi-leafless, or tall semi-leafless), and to compare their yielding ability with other legume-based mixtures (i.e. common and Narbon vetch).

II – Materials and methods

The trial was carried out at the CNR-ISPAAM experimental field 'Leccari', North Sardinia, Italy (40°45'15''N, 8°25'13''E; altitude 24 m a.s.l.). The climate is Mediterranean, with dry and hot summer and mild winter. Average annual rainfall is 550 mm, concentrated from October to May. The site is characterized by a deep alluvial soil, with pH 7.8. *Pisum sativum* L. (pea), semi-dwarf and semi-leafless type (cv Attika, P1) and tall size and semi-leafless type (line 1/27b, P2), *Vicia narbonensis* L. (Narbon vetch, cv Bozdag, N) and *V. sativa* L. (common vetch, cv Barril, V), *Avena sativa* L. (oat, cv Bionda, O) and *x triticosecale* Wittm. (triticale, cv Amarillo, T) were evaluated. A total of 16 treatments were compared: six pure stands (P1, P2, N, V, O, T), eight binary mixtures (P1-T, P1-O, P2-T, P2-O, N-T, N-O, V-T, V-O) and two 4-species mixtures (P1-P2-O-T, V-N-O-T). Fertilizers were applied as 45 kg P_2O_5 ha^{-1} in all plots plus 30 kg N ha^{-1} in cereals monoculture and 15 kg nitrogen ha^{-1} in legumes and legume-based mixtures before sowing. Nitrogen fertilization was repeated at the end of winter. Broadcasting seeding of plots was done in mid-November 2012 following a randomized complete block design with four replicates. Plot size was 12 m^2 (3 m x 4 m). Germinable seed rate (no. m^{-2}) was 70 for P1, P2, and N, 140 for V and 280 for O and T. In binary mixtures and 4-species mixtures, seed rates were halved or reduced to a fourth, respectively. Plots were entirely rainfed. Harvesting was carried out when cereals were at flowering stage, on May, 9th 2013. Plants were cut at 2 cm above the soil from a 1 m^2 sampling area at the centre of each plot. Each mixture component and unsown species were separated from the resulting sample and weighted. A subsample was dried in ventilated oven at 65 °C up to constant weight and re-weighted, in order to estimate the aboveground dry matter yield (DMY) of both sown and unsown species. Phenological stages were observed weekly from germination to harvesting and assigned when at least 50% of plants of the whole plot showed a specific stage. Meteorological conditions were registered during the trial.

One-way ANOVA was carried out using the software Statgraphics Centurion xv. Homoscedasticy of data was assessed by Bartlett's test. Mean differences among treatments were separated by LSD test at 0.05 probability level.

III – Results and discussion

Meteorological pattern. Total rainfall from seeding to harvest was 495.9 mm. A small amount of rain fell after sowing in autumn, but winter was unusually wet. Monthly mean temperatures showed slightly higher values than annual average mean temperatures in January (+1°C) and lower values in February (-1.3°C).

***Phenology*.** For all species and treatments, seedling emergence occurred eleven days after sowing. Both pea varieties flowered 57 days before the flowering stage of oat and 51 days before for triticale (Table 1). Nevertheless, P1 showed ripe brown pods and dry seeds when O was at booting stage and T showed the first awns. P2 showed some dry pods and seeds at the base of plant only at harvesting, when cereals were at flowering stage. P1 was too early maturing in binary mixtures compared to oat and triticale. Conversely, harvesting stages of vetches and cereals matched, as V and N flowered when O and T were at heading stage. Consociation did not affect phenology of species in the cereal-legume mixtures.

***DMY of sown and unsown species*.** DMY of sown species ranged between 5.0 and 7.3 t ha^{-1} with significant differences among treatments (Fig. 1). The average DMY was 6.1, 6.4 and 6.3 t ha^{-1} in monocultures, 2- and 4-species mixtures, respectively. DMY of V-N-O-T (7.3 t ha^{-1}) and V-O (7.1 t ha^{-1}) differed significantly from DMY of P1-O (5.2 t ha^{-1}), P1-P2-O-T (5.3 t ha^{-1}) and P2 (5.0 t ha^{-1}). The other 2-species mixtures showed intermediate DMYs. In general terms, this output indicates an absence of strong interactions between species observed in other trials (Dhima *et al*., 2007), probably due to the lower seeding rate of legumes used in this experiment. DMY of unsown species (DMY_W) was less than 1 t ha^{-1}. DMY_W was significantly higher in P1, P2 and T than in V, N and O (data not shown).

Both vetches showed a very competitive behaviour against unsown species, thanks to their ability to cover soil with a dense canopy. A slight trend towards a higher efficiency in controlling unsown species was shown in binary mixtures where oat was a component. Finally, V-N-O-T showed a better control than P1-P2-O-T mixture.

Botanical composition. The cultivars used in the legume-based mixture showed a good amount of legume biomass on the basis of weight. The percentage of legumes in mixtures (DMY*100/total DMY) ranged between 37% (P2-O) and 87% (V-T) (Fig. 2). In binary mixtures, the contribution of vetches (57.5%) was higher than that of peas (34.9%), especially common vetch (72%). This could be explained not only with the better control of unsown species by vetches compared to peas but also with the higher competitive behaviour of vetches against the other sown species.

Table 1. Phenological stages of legumes and cereals used in mixtures. The phenological stage is expressed as number of days elapsed from sowing. Sowing was carried out on November 15th 2012. Phenological observations ended at day 175 (harvesting)

	Legumes					Cereals	
Phenological stage	**P1**	**P2**	**N**	**V**	**Phenological stage**	**O**	**T**
Stem elongation	97	97	97	97	Tillering	97	97
First flower	110	105	135	143	Stem elongation	127	127
50% flowering	118	118	155	155	Booting	151	148
1st pod	127	127	151	162	Heading	159	155
Pods with green seeds	141	169	169	169	Full flowering	175	169
Pods with dry seeds	151	175	–	–	End of flowering	–	175

P1 = *P. sativum* cv Attika, P2 = *P. sativum* line 1/27b; N = *V. narbonensis* cv Bozdag; N = *V. sativa* cv Barril; O = *A. sativa* cv Bionda; T = *x triticosecale* cv Amarillo.

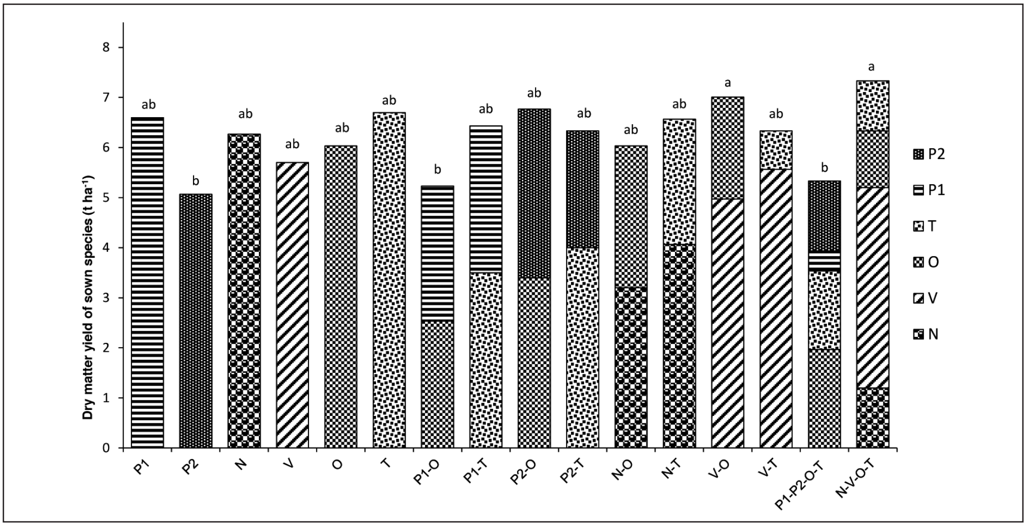

Fig. 1. Dry matter yield (t ha^{-1}) of pea cv Attika (P1), pea line 1/27b (P2), Narbon vetch cv Bozdag (N), common vetch cv Barril (V), oat cv Bionda (O) and triticale cv Amarillo (T) monocultures and their 2- and 4-component mixtures. Different letters show significant differences (P<0.05).

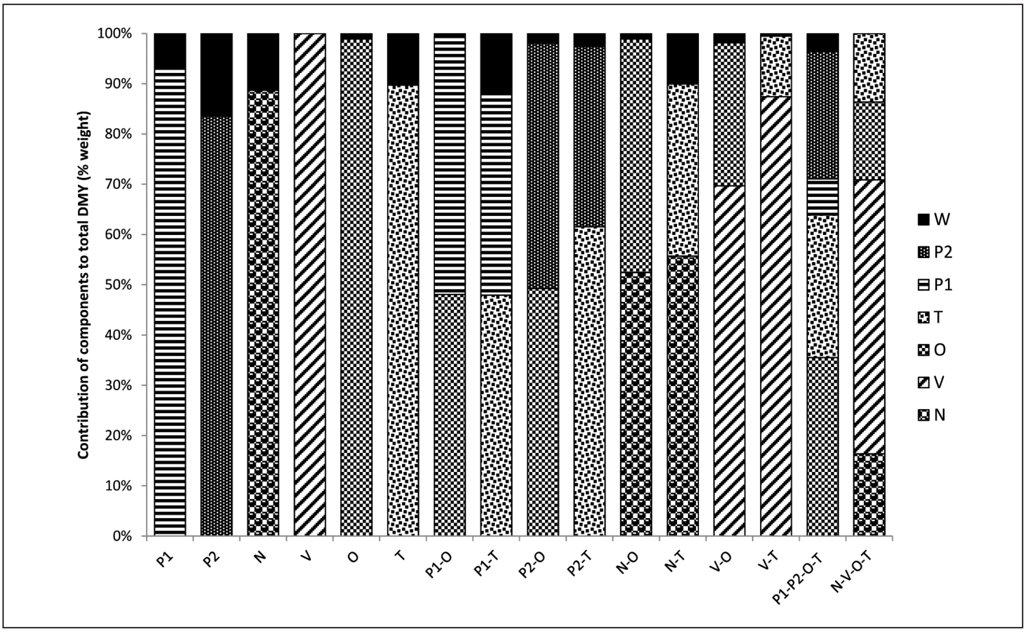

Fig. 2. Contribution (%) to total DMY of DMYs of unsown species (W), pea cv Attika (P1), pea line 1/27b (P2), Narbon vetch cv Bozdag (N), common vetch cv Barril (V), oat cv Bionda (O) and triticale cv Amarillo (T) in monocultures, binary and 4-component mixtures.

IV – Conclusions

These preliminary results allowed identifying some mixtures with a good DMY and a favourable botanical composition, i.e. V-O and N-V-O-T. Moreover, some species and varieties in our trial matched for phenology and showed a great ability in controlling unsown species. Integrative chemical analyses are needed to assess what are the mixtures with the highest forage quality.

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