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Weed control - a key factor for successful crop associations

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Abstract:

Competition of plants for capture of essential resources for plant growth (light, water and nutrients) is a critical process in natural, semi-natural and agricultural ecosystems. Weed management is one of the key elements of most agricultural systems because it is evaluated that about 10% of agricultural production worldwide is lost because of the competition effect of weeds. This issue becomes with higher interest when we consider crop associations. In Albania crop associations, as such, began their life back in the '60s and started to expand substantially in the 80's. Yet, it should be stated that the studies conducted have focused narrowly on defining solely the components towards achieving high production yield or on their agro-techniques rather than on associations per se. There has been little experimentation in terms of their impact on the quality of crop association production, in the biological control of plant pests and the quality of environment in general. In real terms, the changes they bring to the agro-ecosystems are not quite familiar. In order to identify the advantages and the important functions crop association have over the biological production methods the following study was undertaken primarily to evaluate the weed control of crop associations through determining the efficiency and stability of bilateral crop associations to be recommended for use as critical components in agro-ecosystems. The processing of experimental data was modeled upon the Willey model [20]. From the elaboration of data it resulted that the biggest productive edge is being produced by the association barley + pea. This is being followed by the association of barley with hairy vetch.

Keywords: crop association; intercropping, weed.

1. Introduction

Interplant competition for capture of the essential resources for plant growth (i.e. light, water and nutrients) is one of key factors determining the productivity of natural, semi natural and agricultural ecosystems. Weed management is one of the key elements of most agricultural systems because it is evaluated that about 10% of agricultural production worldwide is lost because of the competition effect of weeds [11]. This issue becomes with higher interest when we consider crop associations. In Albania crop associations, as such, began their life back in the '60s and started to expand substantially in the 80's [6, 17]. Yet, it should be stated that the studies conducted have focused narrowly on defining solely the components towards achieving high production yield or on their agro-techniques rather than on associations per se. There has been little experimentation in terms of their impact on the quality of crop association production, in the biological control of plant pests, and the quality of environment in general. In real terms, the changes they bring to the agro-ecosystems are not quite familiar.

Because of its important role in agro ecosystems, competition has been studied widely and from different perspectives. In our study we are focused in the competition of cereal and legume crops with weeds in crop associations. Crop associations are an integral part of agricultural systems, having a determining impact, especially in eco compatible systems, primarily because they allow for the reduction of chemical fertilizers and herbicides; they boost the fertility content and act as real defenses against erosion. This is why plant associations play an important role in organic agriculture [3, 12, 14, 16]. Above all, they enhance the biological diversity improving considerably the environment quality [4, 19]**.** There are a lot of research in this field and most of it confirms the advantages of cereal legume combinations in general [1, 2, 3, 4, 5, 8, 9, 12, 15, 18]. At any case for specific environmental conditions it is needed to study the specific species that provide the best combination.

One of the major issues confronting the research over crop associations is related to the evaluations of the productive advantages achieved thus far. The questions most likely to arise are: which are the complex effects to be identified and how many-sided could the cropping solutions be? The biggest issues do arise when we make an effort towards identifying the monoculture systems towards which we are

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inclined to compare the crop associations under survey. It is of essence to decide the type of measuring unit which will be most appropriate and open to consideration.

With the single purpose and intent of simplifying research Willey [20] suggests that two fundamental criteria be taken into consideration in the evaluation process of productive advantages: the first criterion is of “biological” nature and is intended for the presence of biological efficient scale and the stability in the crop association system when compared with the monoculture system; the second criterion which is well designed and which is labeled as practical, is designed to determine the concrete advantages of a farmer, who in the running of the enterprise could profit more from a co-association system than from a monoculture system for the same area of land. Below we will deal with the cases of crop association through two cultures, which are the most common ones.

2. Materials and methodology

Crop associations have long been studied for the purposes of evaluating the productive advantages [2, 13 and 19].

The experimentation was set up and conducted next to the EDE center at Agricultural University of Tirana. Two types of cereals were studied: oat (Avena sativa) and barley (Hordeum sp.) as well as two types of legume plants: hairy vetch (Vicia villosa) and peas (Pisum sativum).

The varieties being experimented include the following:

Pure barley
Pure oat
Barley + hairy vetch
Oat + hairy vetch
Barley + pea
Oat + pea
Pure hairy vetch
Pure peas

The experimentation was administered in the grounds of the EDE center, Kamez, Tirana. The experimentation scheme consists of a random block with three reduplications, combining mono-culture and crop association variations. The average size of variations is 21 m^2 (7 x 3 m). Thus, we have 16 variations with three reduplications (experimentation scheme).

The planting technique used was “intercropping” [7, 8, 10, and 12] with separate rows, each 15 cm apart, and with a seed ratio as it is recommended for each plant/variety. The planting was done manually. The planting schedule was 15 September – 15 October.

Each crop has been studied separately and associated; in two nitrogen levels 0 and 100 kg N per ha. Phosphorus and potassium appeared at an optimum doze for all variations. In the course of full vegetation, phenological notes have been taken. In addition, at least 4 times throughout spring in every 0.5 m^2, the weight of wet and dry biomass has been calculated for each variation to determine the course of production in its dynamics. The final harvesting is done upon the full and entire flowering of all its components. The processing of experimental data was modeled upon the Willey model [20] which to the above effect makes a direct reference to two criteria: The biological criterion and the practical one. In this case the analysis will be done only through the biological criterion. During the experiment course the numbering of plants both for intercropping and pure cultivation is done twice; before and after winter.

One of the widely common used parameters is the relative yield total (“relative yield total”, Wit and Van Den Bergh, 1965), which consists in the total of relative yields of components “a” and “b” (RYTa and RYTb) on the basis of the following formula:

$$RYTab = \frac{Ya(b)}{Yaa} + \frac{Yb(a)}{Ybb} = RYTa + RYTb$$

In which Ya(b) is the yield of “a” in associations with “b”, Yb(a) is the yield of “b” in association with “a”; Yaa and Ybb are the respective yields as pure crop with optimum density.

By intending to express the yield of associations in connection to the pure culture area, necessary for comparison purposes, there is some kind of talk about the ratio of the equivalent area or (“land equivalent ratio”, Willey, 1979; Mead e Willey, 1980), which for a an association of two cultures is:

$$LERab = \frac{Ya(b)}{Yaa} + \frac{Yb(a)}{Ybb} = LERa + LERb$$

where in an analogues manner with RYT, LERab is total LER of association and LERa e LERb are lateral LER of separate components and the other terms are those as specified above.

From the various indicators that might have been used as judgment instruments for that matter [20], two appear to be of particular interest. One of them is presented from the CR or (“competitive ratios”; Rao, 1980) which in the case of an association of two crops “a”and “b” is:

$$CRa = \left(\frac{\frac{Ya(b)}{Yaa}}{\frac{Y(b)a}{Ybb}} \right) x \; \frac{Zba}{Zab} = \frac{LERa}{LERb} x \frac{Zba}{Zab}$$

in which Zba is the size of component “b” in the association "ab” and Zab is the size of component “a” in the same association. The other terms correspond with those mentioned above. CRb is produced as an inversion of CRa.

Another indicator that turns out to be very efficient in evaluating the equilibrium scale of competitive activity is the yield suppression ratio YSR, defined for an association with two crops in the proportional ratio 50:50.

$$YSRab = \frac{Ya(b)}{Ya} \Big/ \frac{Y(b)a}{yb} \; for \; Ya(b) < Yb(a)/Yb$$

in which Ya(b) and Y(b) are the yield of the component “a” and “b” respectively associated in density of N/2 and Ya, while Yb are the relevant yields in a pure culture in density of N/2.

3. Findings and discussion

In the following tables below designated no.1 and no.2 the experimentation data have been listed for the yields of sappy and dry matter, in the final harvesting, expressed in g/m^2 according to the association variants. Meanwhile in table no.3 and graphs 1 and 2 data on the realized yield have been presented expressed in q/ha. On the basis of these experimentation data, with reference to the method employed by Willey [20], the indicators have been calculated which do express the efficiency of the associations.

Table 1: Wet matter (g/m^2) in the final harvest

No	Variations	Replications			
		I	II	III	Mean
1	Oat + pea	1763.7	1561.0	1969.2	1764.6
2	Barley	1998.0	2569.7	2070.2	2212.6
3	Hairy vetch	3750.5	4107.0	3907.2	3921.0
4	Pea	2569.2	3277.4	1980.4	2575.7
5	Oat	1137.8	1243.2	1065.6	1148.9
6	Barley + hairy vetch	2249.8	2941.4	1780.4	2323.9
7	Oat + hairy vetch	2180.3	2988.6	1885.9	2351.6
8	Barley + pea	1385.5	4245.8	4107.0	3912.8

DMV 0.05 – 630.6 DMV 0.01 – 875.1

Table 2: Dried matter (g/m^2) in the final harvest

No	Variations	Replications			
		I	II	III	Mean
1	Oat + pea	437.0	326.3	183.2	315.5
2	Barley	566.0	699.4	699.5	654.9
3	Hairy vetch	481.9	566.3	681.9	576.7
4	Pea	606.3	826.4	484.4	634.4
5	Oat	282.9	361.3	298.7	314.3
6	Barley + hairy vetch	449.9	604.2	580.8	545.0
7	Oat + hairy vetch	455.1	617.9	454.9	509.3
8	Barley + pea	813.3	957.3	677.8	816.1

DMV 0.05 – 186.0 DMV 0.01 – 259.4

From the calculation of the indicators it turns out that:

a) As for the association of oat + pea:

$$LERab = \frac{Ya(b)}{Yaa} + \frac{Yb(a)}{Ybb} = LERa + LERb$$

$$LERa = \frac{35}{114.8} = 0.31$$

$$LERb = \frac{170}{257.5} = 0.66$$

$$LERa + LERb = 0.31 + o.66 = 0.97$$

$$LERab = 0.97$$

In such a case when LERab < 1 , the association is inefficient respectively with the pure culture system on account of one or two components.

$$CRa = \frac{(Ya(b)}{Yaa} \Big/ \frac{Y(b)a}{ybb} x \frac{Zba}{Zab} = \frac{LERa}{LERb} x \frac{Zba}{Zab}$$

$$CRa = \frac{LERa}{LERb} X \frac{Zba}{Zab} = \frac{0.31}{0.66} x \frac{1}{1} = 0.46$$

$$CRa = \frac{LERb}{LERa} x \frac{Zab}{Zba} = \frac{0.66}{0.34} x \frac{1}{1} = 2.1$$

$$CRb = \frac{LERb}{LERa} X \frac{Zab}{Zba} = \frac{0.66}{0.34} x \frac{1}{1} = 2.1$$

$$YSRab = \frac{Ya(b)}{Ya} \Big/ \frac{Y(b)a}{Yb} = \frac{\frac{35}{114.8}}{\frac{170}{257.5}} = 0.46$$

b) For the association of barley+ hairy vetch:

$$LERa = \frac{75}{221.2} = 0.34$$

$$LERb = \frac{260}{392.1} = 0.64$$

$$LERa + LERb = 0.34 + 0.66 = 1$$

$$LERab = 1$$

This indicates that association in this variant appears to be equivalent to the system culture by itself, since the inefficiency of “a” (barley) is equal in a proportional manner with increase of efficiency of “b” (hairy vetch). The same amount of yield would have been had, as expressed in clear terms from the lateral LER if the cultural components had been divided in areas at the ratio of 0.34 % to 0.66 %. When the most productive culture would have been the most prevalent, an absolute-based evaluation of yields would conceal a real productive edge in the association and would keep out the judgment in favor of the system with just one culture.

$$CRa = \frac{(Ya(b)}{Yaa} \Big/ \frac{Y(b)a}{ybb} x \frac{Zba}{Zab} = \frac{LERa}{LERb} x \frac{Zba}{Zab}$$

$$CRa = \frac{LERa}{LERb} x \frac{Zba}{Zab} = \frac{0.34}{0.66} x \frac{1}{1} = 0.51$$

$$CRb = \frac{LERb}{LERa} x \frac{Zab}{Zba} = \frac{0.66}{0.34} x \frac{1}{1} = 1.9$$

$$YSRab = \frac{Ya(b)}{Ya} \Big/ \frac{Y(b)a}{yb} = \frac{\frac{75}{221.2}}{\frac{260}{392.1}} = 0.51$$

c) For the association oat + hairy vetch:

$$LERa = \frac{40}{114.8} = 0.34$$

$$LERb = \frac{390}{392.1} = 0.84$$

$$LERa + LERb = 0.34 + 0.84 = 1.18$$

$$LERab = 1.18$$

The component “b” (hairy vetch) in such a case yields 18 % of productive edge. The association is efficient, but not stable.

$$CRa = \frac{(Ya(b)}{Yaa} \Big/ \frac{Y(b)a}{ybb} x \frac{Zba}{Zab} = \frac{LERa}{LERb} x \frac{Zba}{Zab}$$

$$CRa = \frac{LERa}{LERb} x \frac{Zba}{Zab} = \frac{0.34}{0.84} x \frac{1}{1} = 0.40$$

$$CRb = \frac{LERb}{LERa} x \frac{Zab}{Zba} = \frac{0.84}{0.34} x \frac{1}{1} = 2.4$$

$$YSRab = \frac{Ya(b)}{Ya} \Big/ \frac{Y(b)a}{yb} = \frac{\frac{40}{114.8}}{\frac{170}{257.5}} = 0.40$$

d) For the association barley + pea

$$LERa = \frac{85}{221.2} = 0.38$$

$$LERb = \frac{185}{257.5} = 0.72$$

$$LERa + LERb = 0.38 + 0.72 = 1.10$$

$$LERab = 1.10$$

The component “b” (pea) yields 10 % more productive edge, while the association is efficient and stable.

$$CRa = \frac{(Ya(b)}{Yaa} \Big/ \frac{Y(b)a}{ybb} x \frac{Zba}{Zab} = \frac{LERa}{LERb} x \frac{Zba}{Zab}$$

$$CRa = \frac{LERa}{LERb} x \frac{Zba}{Zab} = \frac{0.38}{0.72} x \frac{1}{1} = 0.52$$

$$CRb = \frac{LERb}{LERa} x \frac{Zab}{Zba} = \frac{0.72}{0.38} x \frac{1}{1} = 1.9$$

$$YSRab = \frac{Ya(b)}{Ya} \Big/ \frac{Y(b)a}{yb} = \frac{\frac{85}{221.2}}{\frac{185}{257.5}} = 0.52$$

Table 3: Yield of wet and dried matter according to the varieties (q/ha)

No	*Varieties*	*Yield of wet matter (q/ha)*	*Yield of dry matter (q/ha)*
1	Oat + pea	176.4	31.5
2	Barley + hairy vetch	232.3	54.5
3	Oat + hairy vetch	235.1	50.9
4	Barley + pea	391.2	81.6

Table 4: The calculation of the indicators and the evaluation of efficiency for crop associations.

Crop association	*LER = RYT*		*YSR*	*Judgment*
	Components	**Total**		
Oat+ pea	0.31 0.66	0.97	0.46	Crop association biologically inefficient and not stable
Barley + hairy vetch	0.34 0.66	1	0.51	Crop association biologically equivalent and stable
Oat + hairy vetch	0.34 0.84	1.18	0.40	Crop association biologically efficient but not stable
Barley + pea	0.38 0.72	1.10	0.52	Crop association biologically efficient and stable

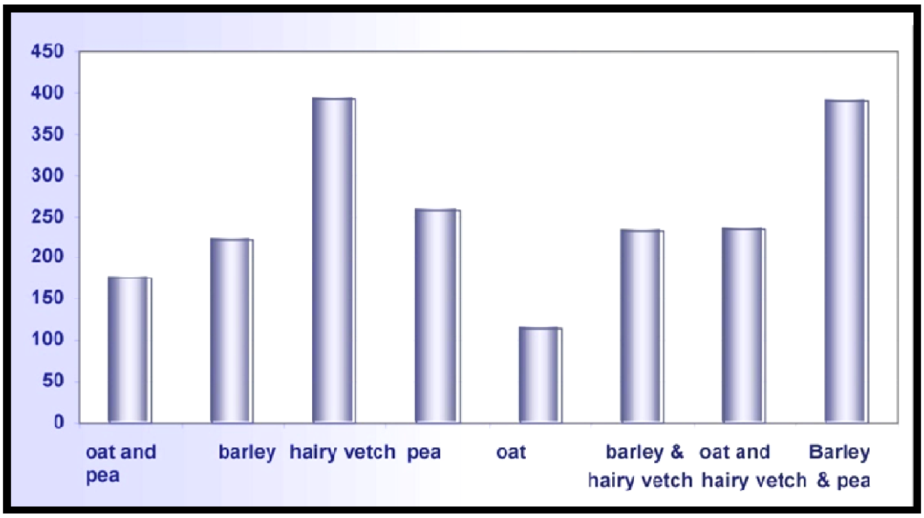

Figure 1: Crop associations and pure cropping yield of wet biomass according to variants (q/ha) in the final harvesting

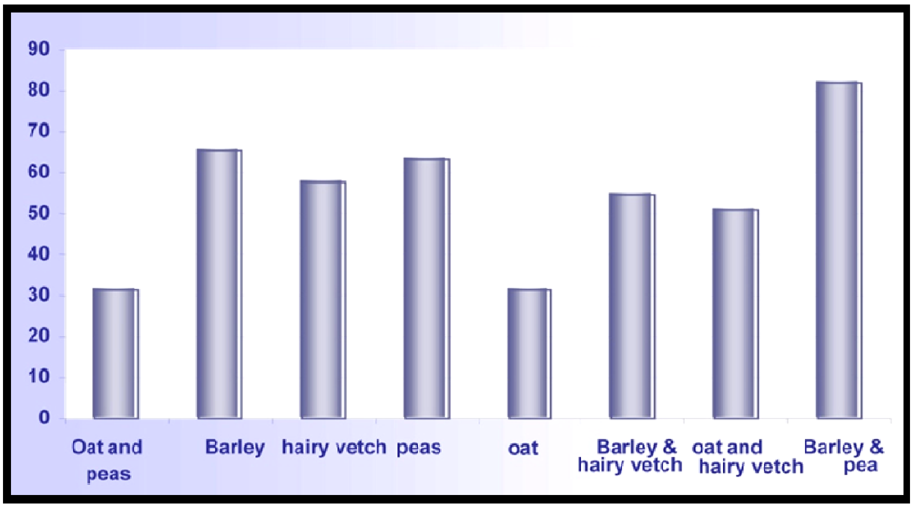

Figure 2: Yield of dry matter (q/ha) according to the variants in the final harvest (from crop associations and pure cropping).

Table 5: Number of plants before and after winter

No.	*Variations*	*Replication I*				*Replication III*			
		No. of plants before winter	**No. of plants after winter**	**No. of weeds before winter**	**No. of plants after winter**	**No. of plants before winter**	**No. of plants after winter**	**No. of weeds before winter**	**No. of plants after winter**
1	Barley	110	94	91	71	170	153	31	26
2	Oat	57	48	45	35	116	100	35	30
3	Barley + hairy vetch	66	54	70	46	63	50	28	14
4	Oat + hairy vetch	127	112	60	44	139	110	36	27
5	Barley + pea	66	58	43	22	100	94	64	32
6	Oat + pea	155	132	76	54	130	120	42	31
7	Hairy vetch	86	80	55	41	130	112	32	24
8	Pea	40	37	50	32	43	40	51	40

Trying to explain these differences we followed the number of plants in all variations in two replications. Weeds are numbered as a separate group (table 5).

DMV 0.05 = 16.0

DMV 0.01 = 23.6

From table no.5 we can see that the combination of barley and hairy vetch provides a better control of weeds. The differences are statistically significant. This fact tells us that this variation creates the higher competition of crops to weeds regarding the use of environmental resources. The variation oat + pea seem to be effective also, especially when the wet weight is considered.

In all variations with pure crops we find a higher level of weeds both before and after winter, confirming the fact that increased competition of crop associations to weeds, compared to pure cropping is one of key factors for the success of intercropping.

Conclusions

From the calculations of indictors according to the method as followed by Willey (1985), concerning the evaluation of efficiency of crop association it turns out that:

The biggest productive edge, in contrast to all the other variants, is being produced by the association barley + pea, a revelation that results from their comparative analysis as indicated above. This variant turns out to be biologically efficient and stable in its production. The two components in their association are efficient.

This is being followed by the association of barley with hairy vetch, in which the two components are equivalent in their production and stable as well. This variant yields huge productive advantages.

As for the variants oat + hairy vetch, which is biologically efficient, an efficiency which results mostly from the production of just one component, hairy vetch, is not stable in its production, that is it does not yield satisfactory productive advantages;

The association oat + pea appears to be poor; it is not biologically efficient and stable in its production, that is why this variant does not yield any productive advantage, as a consequence these two components should not be associated.

Increased competition of crop associations to weeds, compared to pure cropping is one of key factors that support the success of intercropping.

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