COBISS Code 1.01

Agrovoc descriptors: rotational cropping, hops, humulus lupulus, plant protection, land management, integrated plant production, farms, animal husbandry, farm size,

Agris category code: F08, E11

Hop fields in crop rotation

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Received August 10, 2009; accepted January 20, 2010.
Delo je prispelo10. avgusta 2009; sprejeto 20. januarja 2010.

ABSTRACT

A number of factors influenced the increased number of crops on Slovenian farms legal limitation of maize production to two years on the same field, introduction of integrated crop production and certain measures of the Slovene Agri-Environmental Programme. Crop rotation on hop fields that has already been analyzed on 22 hop growing and livestock farms in Spodnja Savinjska dolina in 2008 show that the maize monoculture has been supplemented by some other crops like wheat, barley, lucerne, clover-grass mixtures and high beans; compared to the conventional production in the past, the crop rotation is now longer. Phytosanitary adequacy of two- and three-year rotation could be improved with supplementary crops, that is with fodder crucifers (fodder rapeseed and rape, forage kale), green manure (white mustard, oil radish), legume crops (soya, peas, vetch, field bean, white lupin, crimson clover, Persian clover, Egyptian clover) and compound fodders like Landsberger mixture and mixtures of vetch with oat or barley. Prohibition to sow broad-leafed plants in the quarantine rotation due to hop wilting limits the selection of crops to grasses (Italian rye-grass) and fodder grains (maize, barley), but the farmers could increase the selection of grains with oats, rye, triticale, mixture of wheat and rye, millet, sorghum and Sudan grass. With the use of recommended crop rotations in two-, three- and four-year rotation, we can expect the increased influence of crop rotation on improved health condition of the new hop plantations in the future with simultaneous reduction of the use of pesticides as well.

Key words: hop field, crop rotation, length of crop rotation, species in the crop rotation, phytosanitary importance of crop rotation, fodder supplementary crops, integrated crop production, hop growing and livestock farms

IZVLEČEK

HMELJIŠČA V PREMENI

Zakonsko omejena pridelava koruze na dve leti, uvedba integrirane pridelave in nekateri ukrepi slovenskega kmetijskega okoljskega programa so vzrok, da se povečuje število poljščin na kmetijah. Premena na hmeljiščih, ki smo jo leta 2008 analizirali na 22 hmeljarsko-živinorejskih kmetijah v Spodnji Savinjski dolini, kaže, da so monokulturo koruze razbremenili posevki pšenice, ječmena, lucerne, deteljno-travne mešanice in visoki fižol, premena pa je daljša kot pri konvencionalni pridelavi v preteklosti. Fitosanitarno ustreznost dve- in triletne premene bi lahko izboljšali z dosevki, to je križnicami za krmo (krmna ogrščica in repica, krmni ohrovt) in za podor (bela gorjušica, oljna redkev), metuljnicami (soja, grah, grašica, bob, bela lupina, inkarnatka, perzijska in aleksandrijska detelja) in krmnimi mešanicami, kot so grašljinka (= landsberška mešanica), ovsiga (oves + grašica) in ječmiga (ječmen + grašica). Prepoved setve širokolistnih rastlin v karantenski premeni zaradi hmeljeve uvelosti omejuje posevke na trave (mnogocvetna ljuljka) in krmna žita (koruza, ječmen), kljub temu pa bi kmetje lahko povečali izbor žit z ovsom, ržjo, tritikalo, soržico, prosom, sirkom in sudansko travo. Pri uporabi predlaganih kolobarjev v dve-, tri- in štiriletni premeni lahko v prihodnje pričakujemo večji vpliv premene na boljše zdravstveno stanje novega nasada hmelja ob hkratnem zmanjšanju porabe fitofarmacevtskih sredstev.

Ključne besede: hmeljišče, premena, dolžina premene, vrste poljščin v premeni, fitosanitarni pomen premene, krmni dosevki, integrirana pridelava, hmeljarsko-živinorejske kmetije

1 INTRODUCTION

Hop (*Humulus lupulus* L.) is a perennial crop and a creeper with 40 years lifespan and twelve to fifteen years of exploitation period on modern plantations. In Slovenia it is recently produced on approximately 1600

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ha, mainly in Savinjska dolina, the average yield of cones is 1400 kg/ha (Statistical yearbook, 2008; Statistic information, 2009). Production is based on experience of generations of hop growers and supported by technological advice from the professional experts of the Slovenian Institute for hops research and brewing. Slovene hops, valued by brewers for its high quality biter resins (α–acids), is almost all (90%) sold abroad. The technology of hop production is increasingly oriented in sustainable production and practice shows that a number of hop producing farms has already reached and fulfilled the demands of integrated production and gained the status of integrated producer (Rožič Plazovnik et al., 2008).
Breeding of domestic animals on hop growing farms is traditionally connected with fertilization of hop fields. As a root crop, hop needs a lot of organic matter or humus for optimum growth and manure also improves the quality of the soil.

Similar to other monoculture crop production hop monoculture also is a cause of higher portion of specific pathogens and pests and increased weediness (Friškovec in Škerbot, 2007). Previous experiences have shown that some time off is needed between the time of grubbing-up the old degenerated plantation and planting the new one. The term »rotation« (alternation, replacement; Slovar…, 1993) was recognised and established for the field that is temporary intended for the production of other culture(-s).

In the past hop growers regularly used crop rotation and the duration of the rotation was up to seven years (Sadar, 1961). Phytosanitary benefits of the rotation are increasing with its duration, but only if the broad-leafed plants are being replaced by spring grains and crops from different botanic families (Spanring, 1959; Sadar, 1961; Kocjan Ačko, 1992, 2002, 2004; Plazovnik Rožič, 2008).

In addition to the usual crop rotation, the quarantine rotation is also well known in practice and is used after the destruction of the infected hop production. Only crops that do not serve as a host to the hop pathogens (Zakon o…, 2001) can be used in this rotation. The duration of the quarantine rotation is determined according to the survival capacity of the fungus in the soil without a presence of the host plants (Radišek et al., 2006). The quarantine rotation introduced as a consequence of hops wilting, caused by the funghy *Verticillium albo-atrum* Reinke at Berthold and *Verticillium dahliae* Klebahn, shall last at least four years and only narrow-leaf non-host plants, such as spring grains, maize and grasses can be used in this crop rotation (Čerenak et al., 1999).

In the time of intensive specialization and intensive use of chemicals, experts (Oset, 1991; Veronek, 1995; Friškovec et al., 2002) have been strongly recommending at least two year rotation before planting the virus free seedlings, but on the other side the economic interest forced hop growers to use the shortest rotation possible (Veronek, 1997). Plants used for the rotation give a lot of organic mass for green manure and need cultivation to improve soil structure and air and water retention capacity, they also increase the share of humus and on the other side reduce soil hardness, weediness and the number of pathogens and pests. It is also highly beneficial that the main crop is followed by a supplementary one that remains on the field till the next main crop.

2 MATERIAL AND METHODS

We have studied the crop rotation on hop fields in 2008 by visiting twenty-two selected farms in Spodnja Savinjska dolina. Farmers, skilled hop growers and livestock breeders have answered our questions and provided information on the size of their fields, crops, crop rotation, fertilization and livestock production.

Based on these notes we have determined the duration of crop rotation, which crops are used in the rotation and calculated the total production of individual crops. We believed that important differences would be detected between the farms in the duration of rotation and in the number and species of crops used for the rotation. Due to the livestock production we expected that the fodder crops would be predominantly used in the rotation instead of the crops for human consumption.

We have processed the answers with methods of analysis, synthesis, generalization and specialization and used referrals to domestic and foreign realizations, principles of crop sequence and results of similar research. Using the correct order of rotation we have composed two-, three and four-year biologically balanced crop rotations that can bring a lot of benefits to hop growers in the future.

2.1 Description of hop growing and livestock farms in Savinjska dolina

Hops is produced on all farms that we have studied, being the main crop on half of them; twenty-one farms also have the livestock production which reflects the close interconnectedness of both types of production. On these hop and livestock producing farms there is 276.7 ha of hop fields, 192.7 ha of other crops (80 ha less than hops) and the least – 107.1 ha of meadows. Our calculations show that the average arable land per individual farm is 23.6 ha, out of that – 12.5 ha

is under hops. More than half of farms have over thirty ha of land including forests with the average of 6.5 ha per farm.

On the majority of farms (82%) there is over one hundred years tradition in hop growing, so the family members have different generation connections to various technologies of hop growing and are excellent connoisseurs of hop growing history in Savinjska dolina. Due to financial benefits more than half of farms have fields and hop plantations included in the measures of integrated crop production.

On the livestock farms they breed young male bovine animals for fattening (total of 269 animals), the total number of milking cows is 197, total number of calves - 100 and 90 breeding heifers. Seventeen farms have pigs and five have horses. There is an intensive poultry production on two farms – turkeys in two and chickens in five terms.

To fertilize hop fields all farms mostly use manure, six of them using liquid manure and slurry. Twenty farms use mineral fertilizers during the growing period, mainly nitrogen, till now - green manure was sown only on six farms.

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3 RESULTS AND DISCUSSION

3.1 Length of crop rotation and number of crops in the rotation

More than half of farmers grubb-up hops at fifteen years of age, the rest of them at twenty years. The majority of plantations have been grubbed due to reduced yields and low fertility of older plantations, also the introduction of a new variety is a common reason for grubbing old plantations. Introduction of quarantine rotation is becoming more common cause for grubbing the whole or part of the plantation – we have recorded it on thirteen farms.

Despite knowing and realising the phitosanitary importance of a longer crop rotation on new hop plantations, fourteen growers used two-year rotation and seven growers used three-year crop rotation. One-year rotation was recorded at one grower who only works in plant production. The main cause for prolonging the time of the rotation is the introduction of measures of integrated crop production that demand two-year rotation (Tehnološka navodila za IPP, 2008). Under the conditions of market economy the short term economic interest contradicts the recommendations of experts for the multiannual rotation that is why it will not be easy for the hop growers to fully implement and use the crop rotation. On the studied farms they produce two to four crops within the rotation, mostly as the main crops. For closed and biologically harmonised crop order the supplementary crops, mostly fodder, manure and supplementary crops are missing from the rotation.

3.2 Species of crops in crop rotation

Studied farms are different also considering the species of crops used within the rotation influenced mainly by the type and age of animals they breed, the purpose of their production and the duration of the rotation.

Although maize (*Zea mays* L.) and other root crops as sugar beet (*Beta vulgaris* L. var. *altissima*) use a lot of nutrients from the soil and due to the late harvest with heavy machinery destroy the soil structure, maize is energetically and in terms of income an irreplaceable fodder crop. It is sown on one third of hop fields in rotation (31%), out of which 23% of land is used for the production of silage maize. We assume that the western corn rootworm (*Diabrotica virgifera virgifera* LeConte), which is the cause for legal limitation for the maize production of two years on the same grounds, is less harmful to the maize being sown within the crop rotation compared to the production outside the hop fields. It is true that corn borer (*Ostrinia nubilalis* L.) also affects maize and hops. Unploughed maize and hop remains are the cause of extensive multiplication of corn borer larvae that can also cause damage on beans, peppers, tomatoes and some ornamental plants (Majer and Žolnir, 2002; Rak Cizej et al., 2009). On some fields in crop rotation juicy remains of corn stalks in the ground have been the cause of increased numbers of May beetle larvae (*Melolontha melolontha* L.) during some previous years.

From grains (23.5% of fields) wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) are the dominant ones within the rotation, mostly used as pig or poultry fodder. With the exception of few fields of spring barley and oats there was no rye (*Secale cereale* L.), triticale (*Triticosecale* Wittm.) or mixture of wheat and rye in the crop rotation. Millet (*Panicum miliaceum* L.), maize, cut green as grass, sorghum (*Sorghum bicolor* L.) and Sudan grass (*Sorghum sudanense* (Piper) Stapf.) could be sown as supplementary crops.

The use of high beans (*Phaseolus vulgare* L.) in the rotation (20.5%) is important not only for its favourable influence on soil fertility, but also for the use of hop wires. Jabelski stročnik variety of beans (known to consumers and farmers also as »the grey bean«) is becoming very popular for its culinary quality and for the income that it brings. High beans are economically important crop in the rotation on fourteen out of twenty-two farms. Hop growers do not have much work growing these beans, late maturity is also a good feature since it ripens after hop is already picked and maize has been silaged.

Other legumes could also be tested for sowing in the rotation, such as field peas (*Pisum sativum* L.), especially varieties with tendrils so it needs no support, vetch (*Vicia* sp. L.), soya (*Glycine max* L.), field bean (*Vicia faba* L.) and white lupin (*Lupinus albus* L.). Varieties with shorter growing season or those sown in combination with other crops that can be used as hay or silaged in vax maturity of grains are more suitable for the crop rotation. Fodder legumes, on their own or in mixtures with grasses, are now used on 10.3% of fields in rotation. For lucerne (*Medicago sativa* L.) with four- to five-year use, the optimum use exceeds the duration of rotation that is the reason that it is rarely used on the fields in crop rotation. In addition to favourable characteristics for the soil fertility, also detrimental affects of the lucerne crop on a new hop plantation can be detected. There is an increased danger of underground pests, such as vole (*Arvicola terrestis* L.), that remains in the ground after planting of a new hop plantation and in numerous cases destroys a plantation by gnawing the hop rootstock. More suitable selection would be red clover (*Trifolium pratense* L.) and white clover (*Trifolium repens* L.) with slightly shorter exploitation period. The selection of fodder legumes for sowing in the rotation could be variegated by supplementary crops with short growing period such as crimson clover (*Trilolium incarnatim* L.), Persian clover (*Trifolium resupinatum* L.), Egyptian clover (*Trifolium alexandrinum* L.) and Landsberger mixture, that is the mixture of crimson clover, vetch and Italian rye-grass. With the goal to produce more protein feeding stuffs on their own fields, the growers in Savinjska dolina could again start sowing previously known mixtures of common or winter vetch with grains like oats, barley, rye, wheat or triticale.

The oilseeds - pumpkin (*Cucurbita pepo* L.) and rapeseed (*Brassica napus* L. var. *napus*) and root crops - sugar beet and cabbage (*Brassica oleracea* L.) were only seen on few fields - 14.7% of total fields in rotation. After closure of the Ormož sugar factory in 2005, farmers stopped growing sugar beet. At first it seemed that the rapeseed will replace the sugar beet on Slovene fields (Friškovec in Škerbot, 2007), but the production of rapeseed for biodiesel did not take on on hop farms. Compared to rapeseed production for biodiesel - fodder cruciferous like winter fodder rapeseed (*Brassica napus* L.), turnip rape (*Brassica rapa* L.) and forage kale (*Brassica oleracea* L. convar. *acephala*) , and also root crops like oil radish (*Raphanus sativus* L. var. *oleiformis* Pers.) and white mustard (*Sinapis alba* L.) have proven to be more interesting crops for livestock farms. For green manure phacelia (*Phacelia tanacetifolia* Benth.) could also be used. Fooder rapeseed was used for the green manure in the crop rotation only on one farm, but as a green manure – it is valued on hop plantations when sown between the rows.

Pumpkins for production of oil are grown on two farms; they used the pumpkin oil at home or sold it, and feed the pericarp and fleshing to the pigs. On one farm they started shelling pumpkin seeds and selling them fresh or toasted.

All farmers are informed about the quarantine rotation. Due to the hop wilting it was introduced on thirteen farms, that is more than half (59%) of all studied farms. Winter wheat and winter barley are the prevailing crops in the quarantine rotation, followed by maize and sown grass, mainly Italian rye-grass (*Lolium multiflorum* Lam.). Farmers could also include oats, rye, triticale, mixture of wheat and rye, millet, sorghum and Sudan grass.

3.3 Proposals for the crop rotations on hop fields

Although the multiannual grasses and clovers have most favourable influence on physical, chemical and biological structure of the soil, their growing period hinders thorough processing and sanitation of fields due to certain pests and disease agents on hops. Since the duration of the rotation will not be importantly prolonged in the future, we have set up six recommended rotations for two-, three- and four year rotation (Tables 1, 2 and 3). Four year rotation (in the 1st and 4th case) follows the example of biologically harmonised Norfolk crop rotation with 50% share of cereals and 25% share of root crops and legumes (Butorac, 1999; Diepenbrock et al., 2005).

Table 1: Recommended crop rotations for two-year crop rotations on hop fields

Order of rotation	1. rotation	2. rotation	3. rotation
1. year	winter wheat or triticale or rye + fodder rape or white mustard for the green manure	grain maize or silage maize	oil pumpkins or cabbage
2. year	winter barley + Landsberger mixture	spring barley or spring oats + winter fodder rapeseed or oil radish for green manure	spring oats + fodder rapeseed for animal feed or green manure, in case of cabbage – phacelia for green manure (also honey plant)

Order of rotation	4. rotation	5. rotation	6. rotation
1. year	spring barley + red clover (sub-crop)	spring or winter barley + maize for green forage or sorghum or Sudan grass	triticale or rye + phacelia for green manure (also honey plant)
2. year	red clover	high beans or soya or field beans or white lupin for grains	mixed crop of field peas and barley for grains or field peas with tendrils as pure crop

Table 2: Recommended crop rotations for three-year crop rotations on hop fields

Order of rotation	1. rotation	2. rotation	3. rotation
1. year	winter wheat + forage kale or fooder rapeseed	grain maize or silage maize	oil pumpkins or cabbage
2. year	high beans	spring barley + millet	spring oats + white mustard for the green manure
3. year	spring barley or oats + phacelia for green manure	mixture of oat and vetch + fodder rapeseed	Persian or Egyptian clover

Order of rotation	4. rotation	5. rotation	6. rotation
1. year	winter wheat + forage kale	grain or silage maize	oil pumpkins
2. year	spring barley + red clover (sub-crop)	high beans or soya or field bean for grains	mixed crop of fodder peas and grains barley or fodder peas with tendrils as pure crop
3. year	red clover	spring or winter barley + Landsberger mixture	Winter rye or triticale + phacelia for the green manure (also honey plant)

Table 3: Recommended crop rotations for four-year crop rotations on hop fields

Order of rotation	1. rotation	2. rotation	3. rotation
1. year	grain or silage maize + crimson clover	grain or silage maize	Cabbage
2. year	spring barley + sorghum or Sudan grass for forage	spring barley + fodder carrots	spring oats + turnip
3. year	high beans or grain soya	Persian clover	spring oat and common vetch
4. year	winter wheat or triticale + forage kale or fodder rapeseed or oil radish for the green manure	winter wheat or triticale + phacelia or white mustard for the green manure	winter triticale or rye + forage kale or fooder rapeseed

Order of rotation	4. rotation	5. rotation	6. rotation
1. year	grain or silage maize	grain or silage maize	oil pumpkins
2. year	spring barley + red clover (sub-crop)	high beans or soya or field bean for grains	winter wheat + Italian rye-grass or grass-clover mixture
3. year	red clover	grain or silage maize	Italian rye-grass or grass-clover mixture
4. year	winter wheat + phacelia	spring or winter barley + Landsberger mixture	spring barley + oil radish for the green manure

When looking for new crops that could be included in the crop rotation some people are contemplating the introduction of hemp (*Cannabis sativa* L.) that belongs to the same botanic family (*Cannabaceae*) as hops. We have to mention the increased danger of hemp flea beetle (*Psylliodes attenuatus* Koch) attack that can completely destroy the first year plantation (Friškovec et al., 2002).

4 CONCLUSIONS

Following are the conclusions we have reached based on the analysis of the crop rotation and crops used in the rotation on hop fields:

- In recent years the hop growers gave increased attention to improvement of the soil fertility after grubbing up the old plantations and to all necessary phytosanitary measures before planting a new plantation. They are prolonging the crop rotation; on more than half of studied hop growing and livestock farms they used two-year rotation, on seven farms they used three-year rotation and one-year rotation on only one farm.
- Since 2003, when majority of farms joined the measures of integrated crop production, the selection of crops in the rotation is improving. Before that year mostly maize was sown in the rotation, which further depleted and wearied the soil, now – due to the environmental measures - farmers also decide to sow the other cereals, beans, grasses, clover-grass mixtures, lucerne, pumpkins and cabbage.
- Despite the fact that maize as a root crop is not best suited for the crop rotation, due to the livestock production it still remains the most sown crop, on second place we can find barley and wheat, mostly used for animal feed.
- The production of high beans is becoming more important; hop growers can use hop wires for its production. Also other grain legumes, like field peas with tendrils, field beans and soya as pure crops or mixed with cereals could serve as source of proteins in animal feed. Hop growers should only be informed of the technology to reduce the fear of technical difficulties of their production and harvest. Multiannual hay crops (lucerne, mixtures of grasses and clovers) could be substituted or supplemented with fodder crops, that is with fodder crucifers (fodder rapeseed and rape, forage kale) and green manure (white mustard, oil radish), legumes (soya, field beans, vetch, phacelia, crimson clover, Persian or Egyptian clover) and fodder mixtures like Landsberger mixture and mixture of vetch with some cereals.
- Introduction of winter oil rapeseed as a favourable crop in the rotation shows that we could not successfully establish rapeseed production for biodiesel. Hop growers realised the positive

influence of sowing fodder rapeseed between the rows against weeds, erosion and for green manure. Most likely they will use it for these purposes also in the future (Ur. l. RS št. 18/07 in 124/07).

Wheat and barley are the main crops in the quarantine rotation, maize is on the second place and grasses and grass mixtures on the third. Selection of narrow-leafed crops could be increased by oats, rye, triticale, mixture of wheat and rye, millet, sorghum and Sudan grass, some of them sown as additional crops.

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