UDC: 631.52:633.1
Review paper*

Acta Agriculturaae Serbica, Vol. VI, 11 (2001) 39-49

Acta Agriculturae Serbica
FACULTY OF AGRONOMY • CACAK •

Some Possibilities in Increase of Small Grains Production

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Abstract: Small grains cereals, especially wheat, have great importance as a source of food for an ever growing world population and in economy of each state as well. On the end of XX century, agriculture is confronted between the need for increasing of food production and degradation of natural resources. The purpose of science is to help obtaining the yield as high as possible, to provide growers with the new varieties, necessary seed and plant health management and growing systems, and in such a way to ensure both a higher yield potential and the means to produce cereals more nearly at its potential. In order to help in realization of this goal into perspective, it is useful to think about sustainable improvement of grain productivity and quality in small grains.

Key words: Absolute, attainable, affordable and actual yield, small grains, sustainable agriculture.

Introduction

Production of maximum economic yield (MEY) includes the breeding of high yielding (short and stiff) varieties, use of high rate of seed for a dense stand, the application of starter P and K fertilizers and split applications of nitrogen and pesticides. However, the relative productivity varies widely in the world. According to McNamara (Swaminathan, 1996) if Japan could produce 6,720 kg of grain per hectare in 1970, then Africa with its 1,270 kg, Asia with 1,750 kg and Latin America with 1,060 kg have an enormous potential for expanding

* Presented on International Workshop "Integrated and Sustainable Rural Development Strategy. The Perspectives for Central European Countries" organized on December 4th and 5th, 1998 in Kragujevac

productivity. This great differences in productivity arises from the evolution of a symphonic approach to agricultural development in the developed countries. According to Swaminathan (1996) three major components of a symphonic agriculture are: 1- improved technologies which are economically viable and ecologically sustainable; 2 - the existence of effective institutional mechanisms for the generation and transfer of skills and knowledge, that is, the means to link know-how to do-how; and 3-government policies in the areas of land tenure, pricing, and marketing that permit full expression of the potential of new technology. "Green Revolution" technologies helped in harnessing the photosyntetic pathway of development, which makes agriculture the largest solar energy harvesting enterprise in the World. However, the fast expanding """greed revolution" unfortunately leads to the unsustainable exploitation of natural resources and to the excessive and unspecific use of chemical pesticides and mineral fertilizers. With regard to seeds and property rights, intensification of efforts in the area of genetic resources, collecting, conservation and utilization, as well as more effective legislation and more suitable to farmers government policy were recommended. Related to this, farmers rights and breeders rights should be mutually reinforcing and not antagonistic. This could lead to higher usage of certified seed in small grain production.

Also, it is important to mention the existence of high coincidence in the World between the importing of food and other agricultural commodities and unemployment in the given country. Food production is an important source of jobs. In such a way importing food have same impact as importing unemployment.

The role of science is to help each farmer to obtain as possible high yield in each year and in each field. To help in realization of this goal into perspective, it is useful to think of the "four A's" of productivity: Absolute, Attainable, Affordable and Actual yields as it was done by Cook and Veseth (1991) and presented on fig. 2.

The absolute yield

This is the yield possible to achieve in the field without influence of limiting factors and it presents the genetic potential of the crop (Cook and Veseth 1991). It is not the theoretical calculated maximum yield which according to Borojevic (1992) is 37500 kg/ha of grain. Absolute yield is at least as great as the World record yield of wheat now which is 14.7 t/ha (Cook and Veseth 1991). The absolute yield is obtained with a modern semi-dwarf and dwarf cereal cultivars created through plant breeding, by growing in ideal conditions and by high technology. Up to nowadays, the greatest improvement in small grains breeding was attained by the higher ratio of grain to straw-harvest index (HI), which improved past 1920 together with grain yield. Swaminathan (1996) points out progress in improving of grain yield in wheat between 1750 and 1980 in some countries of Western Europe. Increase in yield observed only during the last 50 years is largely due to rise in the consumption of artificial fertilizers, the adaptation of high yielding cereal varieties and chemical control of pests, diseases and weeds and increase in labor productivity as a result of mechanization.

As there is shown by Borojević (1990) on the tab. 1, the main genetic advance resulted from the increase in HI from 30% (in the old varieties) to 44% (in the new semidwarf varieties), which made it possible to grow a high crop density of 600 to 800 spike /m^2 and to apply high rates of mineral fertilizers in wheat production.

Tab. 1. Advencement in increasing biomass, grain yield and harvest index (Novi Sda, average 1970-77)

Cultivar	Height	Grain yield (t/ha)	Grain yield (%)	Total biomass (t/ha)	Total biomass (%)	Harvest index (%)
Bankuty 1205 (Hung.)	112	4.42	100	14.50	100	30
San Pastore (Italy)	91	5.91	134	14.91	103	40
Bezostaja 1 (Russia)	90	5.82	132	15.13	104	38
Libellula (Italy)	89	6.44	146	15.43	106	42
Sava (Yug.)	81	6.90	156	15.83	109	44
Siete Ceros (Mex.)	84	6.62	150	15.72	108	42
NS-732 (Yug.)	53	5.88	124	11.37	78	48
Next step	70-80	9.00	204	18.00	124	50

However, the compact stature and ability to produce a dense canopy favors foliage diseases and pests infestations. For this reason there is need to develop a new model of plants and crop productivity and a new varieties tolerant to biotic and abiotic stresses and also a new growing technologies. For the continental part of Yugoslavia the genetic changes of wheat plants could go in the following direction (Borojević, 1990):

1. Increase of harvest index up to 50% on the level of the production of total biomass which has been already reached with semi dwarf wheat varieties. This may lead to the shortening of the straw to approximate 70 cm, but also to the elongation of the spike and increase in the number and weight of grain per spike, which would ultimately result in grain yield increase. The dwarf genotypes (50-60 cm) were not accepted in generally as commercial in Yugoslavia.

2. Increase of the level of total biomass maintaining the harvest index at 50%. This may lead to the increase of elongation of the straw, which in its turn would require a stronger straw to maintain the lodging.

3. Genetic changes should be made in the source capacity (stem, leaves) and particularly in the sink capacity (spike). In the conditions of thick canopy curved and erect position of leaves is favourable, while improvements in the efficiency of photosynthesis can be achieved if genetic transformation in the mesophyle and chloroplasts are affected. This may be used as a breeding criterion only if it brings in leaf area duration, which contributes to prolongation of the period of grain filling.

4. Breeding for resistance to pathogenic organisms (rusts, powdery mildew, fusariose and others) and pests (leaf beetle and others).

5. The spike should be lengthened to 10-15 cm which could bear about 25 spikelets in a thick canopy and the number of grains per spike could be increased.

6. Breeding for high yield and high baking quality should remain in the focus, since wheat is mainly used for bread production. However, efforts should be invested in breeding of special varieties for different requirement.

7. Study of varieties of small grains for specific traits in uptake and use of mineral nutrients, which would be useful in breeding genotypes adaptable to different soils. Further to this point it is necessary to study wheat varieties for genetic variability of the root system, especially in the dwarf varieties.

Brilliant development of molecular biology open new vistas to man in his endeavours to bring about changes in the direction desired. All this demands the joint and coordinated efforts of a vast number of specialists all over the world.

The attainable yield

This is the yield possible in any given environment, year and area. It is limited by climate, weather, depth of soil and other factors that, in generally, we cannot manage. In small grains, the attainable yield is limited in generally by the available water, growing degree-days, temperature extremes, the intensity of sunshine and the day length. It is at least as great as the best yield obtained in some area and management system on a given soil. The absolute yield also may be reduced by low and high temperatures. Knowledge when and where water is the factor limiting the attainable yield has important implications for small grains management including summer fallow. The seeding date should be also advanced to give the crop more time to take the advantage of more water, crops rotation to sanitize the soil and to change the method of tillage and residue retention to conserve water. New varieties can take advantage of more water or to have high water use efficiency. Also, the limiting factors in small grains productivity may be light, carbon dioxid, soil aeration and degradation, plant nutrition and fertility, soil acidity and others. Soil acidity as limiting factor for the growth of roots is the problem in many clay soils.

The macronutrients are essential to the maintenance and function of cells and tissues and are required in the considerable amounts. These include nitrogen, phosphorus, potassium, calcium, magnesium and sulfur. The micronutrients are critical for key processes within the cells and are required in trace amounts. In accordance to Fischer (1981) efficiency of nutrients is the product of its uptake and utilization in the plants. The goal in small grains management must be to maximize the capture of N within the plants, the store soil nitrogen and minimize nitrogen losses. There is a growing interest in the conservation and utilization of biological nitrogen fixing organisms. The reason for this interest is the rapid increase in the energy needed to produce a ton of grain using essentially mineral fertilizer produced from fossil fuel based feedstocks. Deficiency of phosphorus may be the problem especially in acid *species*) that posses the properties of improved efficiency of phosphorus utilization. Application of phosphorus with ammonium nitrogen can also increase its availability to plants. Soil testing is the first important step in fertility management program, but producers must keep in mind that crop rotation, the planting date and other options can influence the need for fertilizers and pesticides application and their effectiveness in small grains production. Soil acidity limits the production capability of wheat and affect many biological processes in the soil. In general, nutrients are optimally available in the range of pH from five to seven. Soil acidity could be corrected only by neutralizing the acidity through the addition of some basic liming material.

According to Milovanović *et al.* (1998) triticale as a new crop and/or source (bridge for transfer) of desirable genes in breeding of wheat could play important role in overcoming of many mentioned problems in small grains production. This species demonstrated great variability and high tolerance to soil acidity, salinity and drought, high air temperatures, high efficiency of phosphorous utilization, high resistance and/or tolerance to some important diseases and pests, high compatibility to weeds and many other desirable traits. In such a way triticale could be considered as very promising sustainable crop.

The affordable yield

Besides of afore-mentioned the affordable yield appears as result of limitations by economics, policy and knowledge and it is determined by the potential value of the actual yield offset by the price paid to achieve that yield. The price includes both the short-term direct costs to the farmer and the long-term costs to the industry and eventually to society. The relative high actual yield of cereals with intensive management practices may be affordable to individual growers, but not for long term. Overfertilization is not only expensive but is also likely to contribute to the current problem of nitrates. Practices such as fallow, mulch tillage and early seeding, which maximize available water and the ability of the crop, have the greatest effect on cereals yields in areas with a low attainable yield. On the other hand crop rotation that minimize the effect of pests and diseases have the greatest effect on grain yield in areas with a high attainable yield. Because the tillages costs, a major goal of cereals management is that must be used as little as possible. It is important to calculate the costs of any agrotechnical measures. Profit is the product of yield increase and grain price minus treatment costs. So, for example pesticide application is economic only if their control or elimination will result in sufficiently greater yield to pay for control measure.

In order to counteract the limiting factors of the environment and to utilize better the existing climatic conditions and the production technology, as many as possible of genetically investments in divergent high yielding varieties should be developed to maintain the economy and the stability of small grains production.

The actual yield

The actual yield is the yield harvested in any given field and it is the outcome of the ability of the crop to respond to or take advantage of the growing conditions counter-balanced by weeds, insects, diseases, nematodes, soil fertility, salinity, acidity, fertilizers, compact soil, frost or other production hazards, as well as interactions between the genotype and environment (Fig. 2). From the first day of seed in the soil to the harvest and even in the bin cereals are at risk from rots, spots, rusts, mildew, smuts, scab, interference from weeds and pest attack or infestations. Knowledge related to the pests and diseases problems likely to affect the health and quality of small grains and how to avoid or manage them is crucial in elimination or minimization of the gap between the attainable and the actual yields. Elimination of the causer of diseases, pests and weeds by the agrotechnical, chemical, biological, physical, mechanical and administrative measures is possible, but, the greatest attention must be turned to the possibilities of genetics and breeding of resistant and tolerant cultivars.

In the period 1948/52 the average grain yield of wheat in Yugoslavia was 1,14 t/ha and percent of increasing to 1981/85 was about three times (according to FAO report). Maximum grain yield of winter wheat in Yugoslavia nowadays surpassed 10 t/ha in production and 12 t/ha in experimental conditions. Growing area of wheat is about 900000 ha with average grain yield 3,58 t/ha, rye on 9000 ha have average yield 1,70 t/ha, barley on 114000 ha with average yield 2,55 t/ha, oats on 72000 ha have 1,74 t/ha (Statistical yearbook of Yugoslavia, 1995); and triticale is grown on about 8000 ha with average grain yield about 3,2 t/ha (estimation - CSG Kragujevac). During the period 1964-1996 more than 250 cultivars of winter wheat, more than 30 of spring wheat, more than 20 of two rowed and 13 of six rowed winter barley, more than 30 of two and six rowed spring barley, 6 of winter and spring oats and 5 of winter and 2 of spring triticale cultivars were approved in Yugoslavia (Anđelković *et al*, 1997,1998). Many of those cultivars were arisen as result of program and models developed by Borojević and Potocanac (1966), Mac Key (1966) and Potocanac *et al.* (1969). Those cultivars were created in generally from germplasm originating from Italy, Russia, Germany, Yugoslavia, France, Poland and many other countries. In such a way these cultivars posses satisfying genetic diversity (in spite of theirs in generally intensive plant type), which enable development of strategy for sustainable production of small grains.

Today, the network of experiments of Federal Commission for Cultivars Approval of FR Yugoslavia, consists of 5 locations for winter wheat and 3 locations for spring wheat, winter and spring barley, winter and spring oats, winter and spring rye and triticale. The experiments must be carried out in three seasons (two if there is not recognized cultivar of given species). New perspective genotypes must be better from the most famous commercial cultivars of given species which are included in every trial as check. Besides the grain yield, the resistance to low temperatures and the most important diseases, as well as other physiological and technological (quality) traits are included in examination. After the approval of some cultivar it is in generally included in the most important commercial cultivars during 2 to 3 years. For winter wheat there is 40-45 sites for those ""macro trials", while barley, triticale, oat and spring wheat are sown in 5-15 sites all over the Yugoslavia (in different soil and climatic conditions), Fig. 1. In some locations could be carried joint experiments with wheat, barley, oat and triticale. These macrotrials are sown under control and organization of regional Agricultural Stations. Besides grain yield, other traits could be included in investigations. Results of these ""macro trials"plays very important role in the choice and introduction of new cultivars in some area.

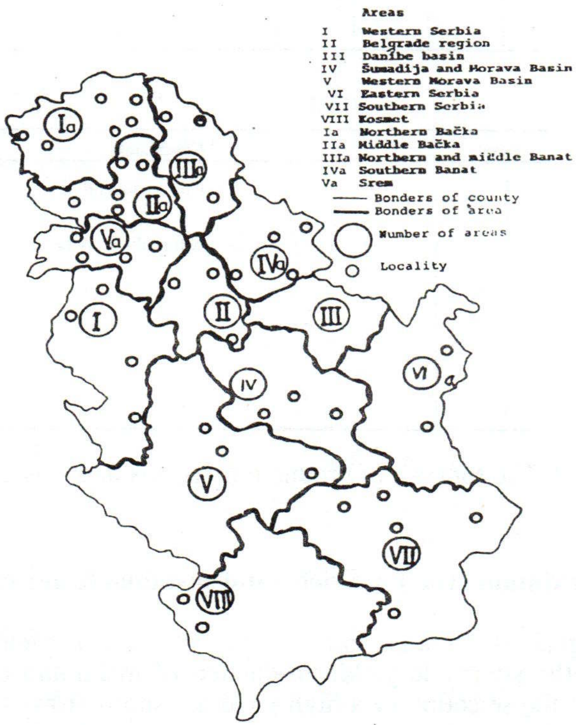

Fig. 1. The network of winter wheat macro-trials

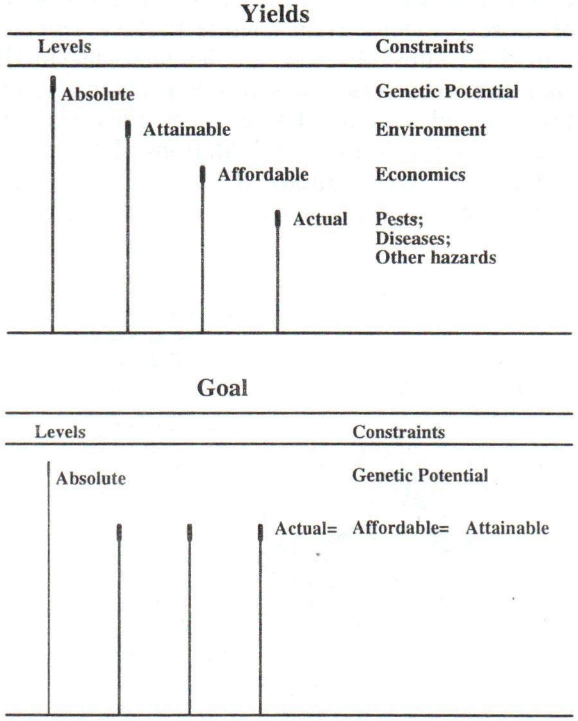

Fig. 2. The four A's of productivity (Cook and Veseth 1991)

Maximum economic yield and sustainable agriculture

The goal of research must be that the actual yield of small grains becomes also the attainable yield. Production of maximum economic yield of cereals include the selection of a high yielding, short-strowed varieties; the use of a high rate of seed with narrow row spacing, for a dense, uniform stand; the application of starter fertilizer containing phosphorus and potassium (if necessary, with the decision based on a soil test) at the time of seeding and some nitrogen either at the time of seeding or before seeding; additional applications of nitrogen during tillering and early stem elongation (split applications, with the total based on the result of soil and possibly tissue test), application of pesticides (if necessary), with the decision based on scanting control weeds, insects and foliar diseases.

In recent years the term "sustainable agriculture" is widely used. Sustainability of the agroecosysteme is the equilibrium between inputs (fertilizers, pesticides, energents and other) and a production. This equilibrium is dynamic and implicit definition of new criterions for evaluation of systems of agriculture production. The sustainability concept brings into the first plan the dimension of intergenerational responsibility (Bathie, 1989)

Until 26 years ago, the term sustainability was measured solely in economic terms. After the UN Conference held in Stocholm in 1972, the environmental parameters were added. This is an approach to farming that systematically attempts to incorporate more biological processes and natural cycles into the farming system; to reduce the use of off-farm inputs with the potential to harm the environment, farmers or consumers; to make more productive use of the biological and genetic potential of plant species; to make an adequate choice of species and variety for given area; to improve the match between cropping patterns, production potential and physical limitations of the land and climate and to give emphasis to profitable, efficient production while conserving soil, water, energy and biological resources. Also, actual the term is integrated pest management which mean the control of the harmful organisms with the reasonable usage of synthetic pesticides and respect of natural resources (Savary and Teng, 1994). The great efforts should be directed in increasing of efficiency of pesticides and in reduction of their impact on the cultivated plants. In such a way pesticides of first generation were applied in more kilograms of active matter per hectare with the large spectrum of action. The recent ones we apply in grams per hectare and they are with a narrow spectrum of action.

Also, the term of alternative agriculture was used. Alternative agriculture range from "organic farming" at one extreme, in which crops and livestock are produced without the use of synthetic chemical fertilizers and pesticides, to similar to maximum economic yield in which synthetic fertilizers and pesticides are used only if it is necessary to achieve a reasonable yield goal efficiently and with minimal negative effects on the environment. All systems of alternative agriculture take a long-term built around crop rotations as the first step to pest and disease control- one of the most effective biological control options farmer have. Swaminathan (1996) developed a strategy for further increasing of food production in India by: 1-characterizing environments and tailoring varieties and management techniques to specific growing conditions, 2- improvement of durum wheats which are more adapted to high temperatures , 3- soil and water care, 4-plant health, 5-increase in protein content, 6-increased efficiency of farming systems, 7-resistance to preharvest sprouting, 8-improved post-harvest technology. Borghi et al (1990) were done the strategy for the future of breed wheat in South of Europe, where the lower productivity can be immediately related to the shorter grain filling period, which is typical of Mediteranean environment in comparison to the wheat areas of North Europe.

For the producers of small grains on the individual farms in Yugoslavia could be recommended usage of both maximal economic yield and some of methods identified with sustainable and/or alternative agriculture. The goal of each farmer should be that the actual yield of small grains is also attainable yield and the methods used to produce this yield must be afforded. For this reason the education of growers should be necessary in the purpose of better utilization of accomplishment of the science in the increase of small grains production. They must be even more innovative and develop the technical skills for more complicated management systems than in the past, to remain competitive economically and to ensure better both a clean environment and a grain product. Society must bear the responsibility for the institutions and political climate necessary to maintain economical production of important sources of food.

References

Anđelković, M., Ksenija Pavlović, A. Djokić, P. Maksimović (1997): Jugoslovenske sorte i hibridi poljoprivrednog bilja. Partenon, Beograd.

Anđelković, M., Ksenija Pavlović, A. Djokić (1998): Personal communication.

Batie, S.S. (1989): Sustainable development: Challenges to the profession of agricultural economics. Ekonomika poljoprivrede (1990), 7-8: 267-287.

Borghi, B., M. Cattaneo, M. Corbellini, M. Perenzin, N. Pogna (1990): Recent results of research carried out in Italy on bread wheat in the context of the cereal policy of the European economic community. Savremena poljoprivreda, 1-2:55-66.

Borojević, S., J. Potocanac (1966): The Development of the Yugoslav Programme for Creating High-yielding Wheat Varieties. Proceedings of Fifth Yugoslav Symp. on Research in Wheat, Novi Sad, 12-18 June, Savremena poljoprivreda, 11-12, 7-36.

Borojević, S. (1986): Žetveni indeks u funkciji povećanja prinosa. XX Seminar agronoma, Zbornik referata, 153-162.

Borojević, S. (1990): Genetski napredak u povećanju prinosa pšenice. Savremena poljoprivreda, 1-2, 25-48.

Borojević, S. (1992): Principi i metode oplemenjivanja bilja. Naučna knjiga. Beograd.

Cook, R.J. and R.J. Veseth (1991): Wheat health management. APS press. USA

Fischer, R.A. (1981): In: Wheat Science-today and tomorrow. 249-269.

MacKey, J. (1966): The Wheat Plant as a Model in Adaptation to High Productivity under Different Environments. Proceedings of Fifth Yugoslav Symp. on Research in Wheat, Novi Sad, 12-18 June, Savremena Poljoprivreda, vol. 14, 11-12, 37- 48.

Milovanović, S.M., B.V. Rigin, I.N. Xynias (1998): Genetic and breeding studies on triticale (*XTriticosecale* Wittmack). In: Genetic and breeding of small grains, Kragujevac (in press).

Potocanac, J., M. Engelman, P. Javor (1969): Wheat Breeding Comprising Yield, Disease Resistance and Quality - Results obtained and Forthcoming Tasks. Proceedings of the Sixth Yugoslav Symp. on Research in Wheat, Kragujevac 9-11. June, Savremena poljoprivreda, 11-12, 17-30.

Savary, S. et P.S. Teng (1994): La protection des cultures dans une agriculture durable. La Recherche, Vol. 25, 271, 1322-1328.

Statistical Yearbook of Yugoslavia, 1995. Federal Statistical Office, Belgrade.

Swaminathan, M.S. (1996): Sustainable agriculture. Towards an evergreen revolution. Konark publishers PVT LTD, Delhi, India.

Šarić, D., Marija, R.J., Protić, M.S. Milovanović (1996): Survey of production and processing value of actual Yugoslav wheat varieties. Proceedings, Faculty of Technology - Novi Sad, vol. 26/27, 3-17.

NEKE MOGUĆNOSTI POVEĆANJA PROIZVODNJE STRNIH ŽITA

- pregledni rad -

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Rezime

Strna žita, a naročito pšenica, imaju veliki značaj kao izvor hrane za sve veću ljudsku populaciju kao i u ekonomiji svake zemlje. Na kraju XX veka poljoprivreda se našla u suprotnosti između potreba za povećanjem proizvodnje hrane, što podrazumeva povećana ulaganja, i degradacije prirodnih resursa. Zato je zadatak nauke u poljoprivredi da pomogne u dobijanju što većeg prinosa svake godine i na svakoj parceli. To se može postići stvaranjem novih, visokoproduktivnih, otpornih i kvalitetnih sorti, obezbeđivanjem proizvodnje kvalitetnog semena i preporukom najpovoljnije tehnologije proizvodnje. Na taj način se povećava potencijalni prinos biljaka i omogućava približavanje stvarno dobijenog prinosa potencijalno mogućem. U cilju realizacije maksimalno ekonomične proizvodnje strnih žita u uslovima održive poljoprivrede razmatrana je mogućnost prevazilaženja limitirajućih biotskih, abiotskih i ekonomskih faktora uz maksimalno smanjenje zagađenja životne sredine. Date su strategije koje treba primeniti u oplemenjivačkom radu, razmatrana je mogućnost racionalne primene pesticida i đubriva na osnovu dijagnoze postojećeg stanja i potreba biljaka i preporučene mere koje treba primeniti na individualnim gazdinstvima da bi se dobio maksimalno ekonomičan prinos u uslovima smanjenog ulaganja u proizvodnju.