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Productivity and economic efficiency of wheat in rotation with cotton

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ABSTRACT- Crop rotation has many benefits for agro-ecosystems production. In order to evaluate two current rotation systems of wheat (*Triticum aestivum* L.) production in Kamalabad region of Fasa, an experiment was conducted during 2015-2016 growing season. The rotation systems were fallow-wheat and cotton (*Gossypium* spp.)-wheat. Research plots were arranged as a randomized complete block design with two blocks. The results showed that seed yield and yield components of wheat were significantly affected by rotation systems. The highest and lowest seed yield and yield components (except 1000 seeds weight and biological yield) and economical value were obtained when wheat was planted after fallow and cotton, respectively. However, the estimation of rotation indices and economic value of rotation systems showed that the highest rotation duration, land use efficiency, production efficiency, and total economic value were obtained from cotton-wheat rotation. Also, the determination of effective traits in wheat yield showed that plant height, spikes per m^2, seeds per spike and harvest index were highly correlated with grain yield. Therefore, although planting wheat after fallow produced more seeds, in terms of total ecosystem production and land use efficiency, this system showed lower productivity and economic efficiency compared to cotton-wheat rotation. Thus cotton-wheat rotation could be adopted by farmers for more production.

INTRODUCTION

Wheat is one of the most important *Poaceae* members which has a vital role in sustainable food security. Its planting area was over 219 m ha with production of more than 713 m t in 2013 (FAOSTAT, 2016). It has been playing an important role in the economy of several countries. An increase in the production of wheat is necessary to provide food security in developing countries (Singh et al., 2010). Cotton is also a significant agricultural commodity throughout the world that is used primarily for its fibbers to manufacture textiles with notable secondary value for its seeds (Hinze and Kohel, 2012). In recent years, there has been increased interest in agricultural production systems in order to achieve high productivity and promote sustainability over time. From ancient times, farmers developed different cropping systems to increase productivity and sustainability; they included crop rotation, relay cropping, and intercropping (Dhima et al., 2007). Crop rotation describes the sequence of different crops grown in the same field. In growing different crops in chronological sequence, positive effects from the current to the subsequent crop can be achieved (Bullock, 1992). Agro biodiversity improvement through crop rotation increases sustainability of the system (Koocheki et al., 2004). Each species can affect the concentration and quality of soil organic matter (SOM) by differential contribution of phytomass, the intrinsic characteristics of crop residues, the root system, and the influence on the microbial community, which are fundamental components of SOM accumulation (Tivet et al., 2013). Agronomists and soil scientists see a clear relationship between crop rotations and sustainability of agricultural production systems (Munkholm et al., 2013). Conventional crop production technologies are not that cost-effective (Jat et al., 2014), are less water efficient (Bhushan et al., 2007) and reduce soil health (Jat et al., 2013) compared to conservation practices. Earlier studies showed that conservation-based management practices are effective for increasing crop and water productivity, and economic sustainability in different cropping systems (Jat et al., 2013, 2014; Das et al., 2014). Berzsenyi et al. (2000) have also found that the yields of maize (*Zea mays*) and wheat were lower in all cases in a monocropping system than the crop rotation. The benefits of crop rotation for land and water resource protection and productivity have been identified, but many of the rotation factors, processes and mechanisms responsible for increased yield and other benefits need to be better understood (Berzsenyi et al., 2000). Popovici and Bucurean (2009) have reported that wheat in rotation with corn produced 48% yield more than in rotation with wheat. The objectives of this study were to determine the land use efficiency and productivity of wheat based on different crop rotation systems in Fasa region, Fars province, Southern Iran.

Materials and Methods

The experiment was conducted during 2015-2016 growing seasons at Research Farm of Fasa region, Fars province, Iran (28°32´ N and 54°15´ E, and 1450 m above sea level). The experimental site is classified as semi-arid climate, with an average annual temperature and rainfall of about 20.3 C° and 301.7 mm, respectively. The fallow-wheat and cotton-wheat rotations were carried out to study seed yield and economic value of the systems. Research plots were arranged as a randomized complete block design (RCBD) with two blocks. Cotton was sown with a row spacing of 0.6 m and a plant density 9 plants m^{-2}. Sowing depth varied with seed size and ranged from 3–4 cm for wheat to 4–5 cm for cotton. This experiment was conducted under irrigated conditions and weeding and hoeing were done when required. Other practices are performed according to what is locally done. Cotton seeds (Golestan cultivar) were planted at 10 June 2015 and after cotton harvesting, wheat seeds were planted on 25 December 2015 in cotton-wheat rotation and on 11 November 2015 in fallow-cotton rotation. In cotton-wheat rotation, cotton was harvested on 19 December 2015 and 6 days after cotton harvesting, wheat was planted. Wheat plants were harvested on 6 May 2016 in both rotations. Plant height, spikes per m^2, seeds per spike, spike length, 1000 weight seeds, seed yields, biological yields and harvest index of wheat were measured after harvesting. To estimate economic value of crops, sale price of crops was multiplied to yield and for each rotation, economic value of crops in the first year was added to economic value of wheat in the second year and considered as total economic value (Beheshti and Soltanian, 2012). The current price of cotton was 0.63€ per kg, and the current price of wheat was 0.32€ per kg. In order to assess cropping systems efficiency, some rotation indices were evaluated:

Rotation duration= Total days of plants present in rotation (Jones and Popham, 1997).

Land use efficiency= Total days of plants present in rotation divided by total days of rotation period (Tomar and Tiwar, 1990).

Production efficiency= Total production of crops in rotation divided by total days of plants present in rotation (Tomar and Tiwar, 1990). The data recorded were statistically analyzed using the procedure of SAS 9.1. Critical difference (CD) values at 5% level of probability were calculated for comparing the treatment means (by Duncan's multiple range test).

RESULTS AND DISCUSSION

Effect of rotation systems on yield and yield components of wheat

The results showed that yield and yield components of wheat were significantly affected by rotation systems and the highest and lowest seed yield and yield components (except 1000 seeds weight and biological yield) were obtained when it was planted after fallow and cotton, respectively (Tables 1 and 2). Seed yield reduction might be due to the delay in wheat planting after cotton. As mentioned earlier, wheat was planted on 25 December 2015 in cotton-wheat rotation and on 11 November 2015 in fallow-cotton rotation. Plants successfully complete their life cycle at favorable conditions in a suitable planting date (Chen et al., 2003).

Table 1. Effect of rotation systems on plant height, spikes number, seeds per spike and spike length of wheat.

Rotation system	Plant height (cm)	Spikes per m^2	Seeds per spike	Spike length (cm)
Fallow-wheat	64a	124a	29a	8.5a
Cotton-wheat	56b	120b	20b	6.5b

Different letters in each column indicate a significant difference (Duncan 5%).

Table 2. Effect of rotation system on 1000-seed weight, seed yield, biological yield and harvest index of wheat

Rotation system	1000 seeds weight (g)	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-})	Harvest Index
Fallow-wheat	33b	1000a	2120b	47.16a
Cotton-wheat	40a	960b	2200a	43.63b

Different letters in each column indicate a significant difference (Duncan 5%)

In late planting, crops do not have enough time to complete growth and indeed have to decrease their phonological stages to complete their life cycle and decrease their growth and ultimately seed yield. In spite of all that and unexpectedly, wheat seed yield was not significantly lower in cotton-wheat rotation than fallow-wheat rotation. Even wheat produced more dry matter in cotton-wheat rotation than fallow-wheat rotation which might be due to positive effects of crops on each other in rotation. Different crops have different requirements (Brankatschk and Finkbeiner, 2015), thus crops which grow in the same field in a sequential process can have significant effects on growth and yield of next crops. A positive relationship was found between crop rotation and sustainable production in agricultural systems (Munkholm et al., 2013). Higher wheat dry matter production after cotton compared to fallow could be attributed to soil organic matter preservation, fertility and soil structure improvement and increase in biodiversity. Crop residues positively affect soil physical, chemical and biological properties and maintain or improve soil fertility for next crops

(Brankatschk and Finkbeiner, 2015). Lower harvest index in spite of higher biomass production in cotton-wheat rotation suggested that this treatment had a weak performance to allocate assimilates to seeds which may be due to shorter life cycle of wheat in cotton-wheat rotation. Thousands of seeds' weight increased in cotton-wheat rotation which might be due to a decrease in spike length and seeds per spike. Plants did not have enough time to produce more seeds in delayed planting; therefore, assimilates allocated to a few seeds. Najafinejad et al. (2004) compared seed yield of wheat by 600 kg ha^{-1} in rotation with cotton to monoculture. Continuous wheat planting tears down the soil in the long term even if it might be economical (Rahmati et al., 2010). The efficiency of biomass production in wheat-fallow rotation was significantly lower than that of wheat-wheat and wheat-pea (*Cicer arietinum* L.) with wheat-fallow (Pilbeam et al., 1998). Continuous wheat-fallow rotation weakens the soil, increases in erodibility and decreases in SOM (Wien hold and Halvorson, 1998). Crop residues remaining on the field have a great influence on creation of positive crop-rotation effects. Even though the occurrence of crop residues is not restricted to crop rotations, as they may also occur in monocropping, they serve as a good example for their effects between different crops grown on the same field (Brankatschk and Finkbeiner, 2015). Anderson (2008) have also reported that crops which have been planted prior to wheat can have a great influence on its yield and yield components. Haddadchi and Gerivani (2009) have also showed that proper crop rotation has significant effects on growth and yield of the next crop.

Economic and agronomic efficiency of rotation systems

It is important to note that the highest wheat economic value also belonged to fallow-wheat rotation due to higher yield of this system (Table 3). It seems that wheat planting after fallow gave the farmer enough time for proper land preparation and on-time planting and thus, plants had enough time to grow better and ultimately produce higher yield. But plants did not have enough time to grow if planted after cotton which led to lower yield. However, the estimation of rotation indices and economic value of rotation systems showed that the highest rotation duration, land use efficiency, production efficiency, and total economic value were obtained from cotton-wheat rotation. Jat et al. (2014) have also reported that the diversified cropping systems affected the net returns which were mainly due to higher yields and differential cost of production. In agricultural practices, crop-rotation is an essential strategy. These effects are, for instance, based on improvements of nutrient availability, phytosanitary conditions and soil structure which increase yields and allow lower application rates of fertilizers and pesticides. Against this background, crop-rotation effects are clearly relevant for assessing environmental impacts of agricultural crops (Brankatschk and Finkbeiner, 2015). Parihar et al. (2016) have also revealed that under multiple challenges, sustainable intensification of corn systems (crop rotation) have potential for meeting future food needs, income security and sustainability of natural resources using conservation agriculture-based management options. In most cases, the yields of the cultivated crops are higher in crop rotation compared to monoculture under identical conditions. The effect of rotation has been demonstrated irrespective of whether the crop rotation contains legumes or non-leguminous crops (Berzsenyi et al., 2000).In particular, selecting proper crops is an important factor towards higher total productivity of cropping systems.

Relationship between yield and dependent traits on yield

The results showed positive and significant correlations between seed yield and plant height (0.992^{**}), spikes per m^2 (0.999^{*}), seeds per spike (0.990^{**}) and harvest index (0.992^{**}), and it seems that spikes per m^2 was the most effective factor in yield formation (Table 4). Spikes per m^2 had the highest correlation with seed yield. In fact, the results suggested a positive relationship between seed yield and plant height, spikes per m^2, seeds per spike and harvest index. Therefore, increasing these traits increased seed yield as well. Thus, crop improvement programs should consider increasing these traits. Manifestation of wheat yield widely fluctuates due to its interaction with the environment because grain yield is a complex inherited character and the product of several contributing factors affecting yield directly or indirectly. Wheat production can be enhanced through development of improved genotypes capable of producing higher yield under various agro climatic conditions and stresses (Inamullah et al., 2006). Selection for grain yield can only be effective if desired genetic variability is present in the genetic stock. Genotypic and phenotypic correlations are important in determining the degree to which various yield contributing characters are associated (Akram et al., 2008).Parihar et al. (2016) have also declared that higher wheat grain yield could be attributed to the higher spike density, grains per spike and 1000-grain weight. It is important to note that yield stability depends on yield components and other characteristics (Kang, 1998). Sokoto et al. (2012)have concluded that spikes per m^{-2}, spikelets per spike, grains per spike, harvest index and 1000-grain weight are the major contributors towards grain yield because these characters had high correlations with grain yield. Thus, direct selection for these characters should be the major concern for plant breeders to increase grain yield and quality.

CONCLUSIONS

The results of this experiment showed that although planting wheat after fallow produced higher seed yield, this system showed lower productivity and economic efficiency compared to cotton-wheat rotation in terms of total ecosystem production and land use efficiency. Therefore, it seems that this rotation could economically and environmentally improve cropping system productivity. These findings suggested that crop rotation was highly productive in terms of yield and economic value. Thus, cotton-wheat rotation could be adopted by farmers for more production.

Table 3. Rotation indices and economic value of wheat as affected by rotation systems

Rotation system	Rotation duration (day)	Land use efficiency (%)	Production efficiency (kg ha^{-1} day^{-1})	Wheat economic value (€)	Cotton economic value (€)	Total economic value (€)
Fallow-wheat	177	49.03	5.64	322	-	322
Cotton-wheat	324	98.18	8.97	309	1230	1538

Table 4. Correlation coefficients between wheat yield and yield components in rotation systems.

	Plant height	Spikes per m^{-2}	Seeds per spike	Spike length	1000- seeds weight	Seed yield	Biological yield	Harvest index
Plant height	1							
Spikes per m^{-2}	0.992**	1						
Seeds per spike	0.999**	0.990**	1					
Spike length	0.861ns	0.907ns	0.855ns	1				
1000- seeds weight	-0.964*	-0.926ns	-0.968*	-0.718ns	1			
Seed yield	0.992**	0.999**	0.990**	0.907ns	-0.926ns	1		
Biological yield	-0.969*	-0.932ns	-0.972*	-0.729ns	0.999**	-0.932ns	1	
Harvest index	0.971*	0.992**	0.968*	0.920ns	-0.877ns	0.992**	-0.885ns	1

^{ns}, * and **: Not significant and significant at 5 and 1% probability levels, respectively

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دانشگاه شیراز

ارزیابی بازده اقتصادی و قابلیت تولیدگندم در شرایط تناوب باپنبه

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واژه‌های کلیدی:
تنوع کاشت
کارایی استفاده از زمین
Triticumaestivum
عملکرد

چکیده-تناوب زراعی به علت داشتن مزایای فراوان، اکوسیستم‌های زراعی را تحت تأثیر قرار می‌دهد. در همین راستا، به منظور ارزیابی دو سامانه تناوبی رایج مبتنی بر گندم در منطقه کمال‌آباد فسا، آزمایشی در سال زراعی ۹۵-۱۳۹۴ انجام شد. سامانه‌های تناوبی کشت گندم (*Triticum aestivum*L.) مورد ارزیابی عبارت بودند از آیش-گندم و پنبه (*Gossypium* spp.)-گندم. نتایج حاکی از تاثیرمعنی‌دار تناوب زراعی بر عملکرد و اجزای عملکردگندم بود، به نحوی که بالاترین و کمترین عملکرد دانه و اجزای عملکردگندم (به استثنای وزن هزار دانه و عملکرد زیستی) به ترتیب در شرایط کشت پس از آیش و پنبه به دست آمد. شایان ذکر است که بیشترین ارزش اقتصادی گندم نیز با توجه به عملکرد بالاتر تناوب آیش-گندم، در این سامانه حاصل شد. اما برآورد شاخص‌های تناوب و ارزش اقتصادی سامانه‌های تناوبی نشان داد که بیشترین طول دوره تناوب، کارایی استفاده از زمین، کارایی تولید و ارزش اقتصادی کل، مربوط به تناوب پنبه-گندم بود. همچنین تعیین صفات مؤثر در افزایش عملکردگندم نیز نشان داد که صفات ارتفاع بوته، تعداد سنبله در مترمربع، تعداد دانه در سنبله و شاخص برداشت، بیشترین نقش را در شکل‌گیری عملکرد آن داشته‌اند. بنابراین اگرچه در این آزمایش کشت گندم پس از آیش منجر به تولیدگندم بیشتر شد، اما این سامانه تناوب از نظر تولیدکل اکوسیستم زراعی و کارایی استفاده از زمین، از بهره‌وری تولید و از بازده اقتصادی پایین‌تری نسبت به تناوب پنبه-گندم، برخوردار بوده است. از اینروسامانه پنبه-گندم می‌تواند توسط کشاورزان در راستای تولیدبیشتر، مورد استفاده قرار گیرد.