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Production of Oyster Mushroom (*Pleurotus* spp.) Intercropped with Field Grown Faba Bean (*Vicia faba* L.)

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ABSTRACT

Few studies have been reported on outdoor production of oyster mushroom as intercrop and to our knowledge, no information is available for its intercropping with field grown faba bean. Therefore, the present field trial was conducted to assess outdoor production of *Pleurotus ostreatus* and *P. columbinus* interplanted with faba bean (*Vicia faba* L.). The mushrooms were interplanted at three different developmental stages of faba bean plants (flowering/pod setting, pod setting/early seed filling and pod development/seed filling stages). Data for basidiocarp yield revealed superiority of *P. ostreatus* over *P. columbinus* for all interplanting treatments. *P. ostreatus* produced higher basidiome yield when placed within faba bean rows at flowering/pod setting or at pod setting/early seed filling stages. The biological efficiency of *P. ostreatus* ranged from 29-45%. However, *P. columbinus* produced its highest basidiocarp yield when placed between faba bean plants at pod setting/early seed filling stage. *P. columbinus* showed biological efficiency in the range of 12-28%. In addition to its higher basidiocarp yield, *P. ostreatus* consistently developed harvestable basidiocarps earlier than *P. columbinus*. An increase of 27%, on average, was detected in faba bean dry seed yield when grown with mushroom intercrop compared to its sole cultivation. This study suggests a feasible integration of non conventional mushroom crop in the higher plant crop production system towards securing food availability while improving income of small farmers. Here, it is recommended to utilize *P. ostreatus* mushroom placed in faba bean field at flowering/pod setting stage to pod setting/early seed filling stage.

Key words: Integration, non conventional crop, outdoor, planting date, *Pleurotus ostreatus*, *Pleurotus columbinus*

INTRODUCTION

Oyster mushroom (*Pleurotus* spp.) of class Basidiomycetes, subclass Hollobasidiomycetidae, order Agricales is an edible macrofungus that can be cultivated and exploited for a profitable agribusiness (Hibbett *et al.*, 2007). Mushrooms are a source of vital human nutrients (Khan *et al.*, 1981; Tewari, 1986) and have medicinal properties like anticancerous, anticholesteral and antitumorous (Quimio, 1976). A wide range of mushroom species naturally grow wild in the forests of hilly areas. Cultivation of Mushroom can be profitably used for bioconversion of agricultural wastes (Bano *et al.*, 1993; Cohen *et al.*, 2002). This technology can limit air pollution associated with burning agricultural wastes and decrease pest and pathogen inoculum (Mandeel *et al.*, 2005). In addition, mushroom cultivation is advantageous in terms of time and space and, therefore, it is interesting issue for poor farmers (Shah *et al.*, 2004).

Several mushroom species are commonly cultivated worldwide in temperate and subtropical areas. Oyster mushroom represents the third largest group of cultivated edible mushrooms (Chang, 1999; Royse, 2002). It can grow where moistened lignocellulosic substrate is found under conditions of suitable temperature and humidity conditions. They can be grown on wide range of agricultural (in the form of straws, leaves, stems, roots etc.) and industrial wastes of byproducts (Zadrazil, 1978). Mushrooms like oyster mushroom are the easiest, fastest and cheapest to grow among the other cultivated ones and efficiently recycle lignocellulosic waste materials. Oyster mushrooms, therefore, are considered to be an attractive crop to cultivate in developing countries. One of the most fascinating reasons would be that most of *Pleurotus* spp. are grown on raw uncomposted agricultural wastes and can utilize various kinds of substrate materials than any other mushrooms. Thus it can be used for biotransformation of lignocellulosic wastes into food while enabling environment conservation via lessening pollution caused by these wastes (Hayes, 1978). Further, the spent substrate can be then used for higher plant crop fertilization in addition to livestock feeding (Kwak *et al*., 2007; Sanchez, 2004).

Mushroom cultivation industry is widely operated indoors. Outdoor cultivation in form of intercrop with field crops is not common and research is scarce in this regard. Except few (Mohammady, 1996; Kirshnamoorthy *et al*., 2005), the authors are unaware of pervious studies of interplanting oyster mushroom in the open field with the higher plant crops. In the study conducted by Mohammady (1996), oyster mushroom (*Pleurotus columbinus*) was interplanted with cauliflower (at the beginning of curd formation) or overwintering egg plant. Kirshnamoorthy *et al*. (2005) studied paddy straw mushroom as inter-crop in maize (*Zea mays*) field. Outdoor cultivation is less capital-intensive and integration of non conventional mushroom crop in existing agricultural system of crop production can help to secure food needs and improve income of small farmers towards better social as well as economic conditions for them.

The objective of this study was to investigate the production of two cultivated oyster mushrooms (*Pleurotus ostreatus*, commonly called tree mushroom and *Pleurotus columbinus*, commonly named blue mushroom) intercropped at three different developmental stages of field grown faba bean (*Vicia faba* L.) plants (flowering/pod setting, pod setting/early seed filling and pod development/seed filling stages).

MATERIALS AND METHODS

The current research trial was conducted in the mushroom production laboratory, Department of Horticulture and in the open field of the Experimental Farm, Agriculture Research Station, Faculty of Agriculture, Assiut University during two consecutive winter seasons (2008/2009 and 2009/2010). Production of two cultivated oyster mushroom species (*Pleurotus ostreatus* and *Pleurotus columbinus*) was assessed as intercrop with faba bean (*Vicia faba* L.) when placed at three different developmental stages of faba bean plants (flowering/pod setting, pod setting/early seed filling and pod development/seed filling stages). Spawn of oyster mushroom used in this study was obtained from Agricultural Research Center, Food Technology Research Institute, Giza.

Laboratory groundwork: Rice straw substrate was moistened thoroughly by soaking in water. Then after the substrate was stuffed 2 h in hot water at 80°C for pasteurization (Bahukhandi and Munjal, 1989; Balasubramanya and Kathe, 1996). Wheat bran (Soliman, 2011) and gypsum (calcium sulfate) were added at rate of 5% based on the substrate dry weight. The pasteurized substrate was left to cool down and to drain excess water until mean moisture of 70%; calculated

Fig. 1(a-b): (a) Photographs show mushroom cultures intercropped within faba bean plants and (b) Mushroom fungus forming basidiocarp

by drying 100 g pasteurized substrate samples in an electric oven at 60°C until constant weight. The pasteurized substrate was manually packaged into clear polyethylene bags of mean thickness 0.2 mm containing 0.5 kg wet pasteurized substrate. The spawn was inoculated at rate of 5% based on wet mass of the substrate. The inoculated substrate was incubated for spawn running at 24-28°C in the darkness.

Open field assessment: After complete spawn running (~3 weeks), the mushroom bags were transferred to the faba bean field for fructification (basidiocarp formation). Polyethylene bags were removed and the cultures were placed in the open field within faba bean plants. The faba bean seeds were planted 25 cm apart on the northern side of 70 cm wide rows on Oct 29th and 30th in the first and second year, respectively. The placement of mushroom in the faba bean field was set at two week intervals starting on Jan 1st in both years. Faba bean plants were at flowering/pod setting (Fig. 1a), pod setting/early seed filling and pod development/seed filling stages on the three placement dates (1st, 15th and 30th Jan) for the mushroom intercrop, respectively. At these growth stages, faba bean plants developed sufficient canopy to provide shade protecting mushroom cultures from subjection to direct sun rays. The average temperature in the experiment site during the intercropping period of time ranged from 12-18°C. The minimum temperatures were 5-7°C while the maximum temperature recorded were 20-30°C. The relative humidity ranged from 70-75%. The substrate moisture of the mushroom cultures was maintained by light daily watering during the whole cropping period. Mushroom basidiocarps were harvested about a week after pinheads (primordia) formation that was as soon as the gills were well formed and while the edge is still curled under (Fig. 1b). A factorial experiment was conducted for 6 treatment combinations (2 mushroom species X 3 interplanting dates) in randomized complete-blocks with 4 replicates. Each treatment per replicate was presented by 3 faba bean rows and 10 bags per row. The experiment contained an additional seventh plot per each replicate grown with sole faba bean crop. This plot served as pilot to test the dry seed yield of faba bean monocrop against intercrop.

Measurements and statistical analyses: The data were recorded for days lapsed to visible pinheads (primordia) formation, basidiocarp yield (g/culture), number of basidiocarps per culture and average basidiocarp weight (g/fruit). Biological Efficiency (BE) was calculated as follows (Ahmed, 1995; Kirbag and Akyuz, 2008):

$$\text{BE (\%)} = \frac{\text{Weight of fresh mushroom basidiocarps}}{\text{Dry weight of the substrate}} \times 100$$

Data were also recorded for faba bean dry seed yield. All data were subjected to analysis of variance (Gomez and Gomez, 1984) and means were compared using "The Least Significant Difference" (LSD) Test at 0.05 probability level. Student's "t" test was used to compare dry seed yield of monocroped and intercropped faba bean.

RESULTS

Days lapsed to visible pinhead formation were affected by mushroom cultivar ($F_{1, 15}$ = 113.2; $p<0.05$ and $F_{1, 15}$ = 127.1; $p<0.05$, for the first and second years, respectively), developmental stage of faba bean plants at intercropping time for mushroom (flowering/pod setting, pod setting/early seed filling and pod development/seed filling stages) ($F_{2, 15}$ = 43.8; $p<0.05$ and $F_{2, 15}$ = 52.1; $p<0.05$, for the first and second years, respectively) and their interaction ($F_{2, 15}$ = 4.4; $p<0.05$ and $F_{2, 15}$ = 5.59; $p<0.05$, for the first and second years, respectively) (Table 1). In both years of this study, *Pleurotus ostreatus* mushroom formed pinheads about 12 days after placement in the open field within faba bean plants at flowering/pod setting stage (Table 1). Pinheads (primordia) of *P. columbinus* appeared after about 14 days in the second year and 16 days in the first year. When placed at pod setting/early seed filling and pod development/seed filling stages, primordia of *P. ostreatus* were visible 13 days and 15 days, respectively in the first year. In the second year, this was 12 and 15 days. *P. columbinus* showed its pinheads 3 and 6 days later than *P. ostreatus* in these two interplanting conditions in the two years. As shown in Table 1, *P.ostreatus* mushroom

Table 1: Days lapsed to visible pinhead formation of two cultivated mushroom species (*Pleurotus ostreatus* and *P. columbinus*) inter-placed within faba bean (*Vicia faba* L.) plants in the open field at three different stages of the faba bean plant development in 2008/2009 and 2009/2010[(1)]

Developmental status of faba bean plants at intercropping time	Mushroom cultivar (*Pleurotus* spp.) 2008/2009				2009/2010			
	P. ostreatus	*P. columbinus*	Diff.[(2)]	Mean[(3)]	*P.ostreatus*	*P. columbinus*	Diff.[(2)]	Mean[(3)]
Flowering/pod setting	11.8±0.48	15.5±0.50	3.7*	13.7[b]	11.3±0.25	14.3±0.48	3.0*	12.8[c]
Pod setting/early seed filling	13.0±0.41	16.0±0.40	3.0*	14.5[b]	11.5±0.27	17.8±0.63	6.3*	14.7[b]
Pod development/seed filling	15.0±0.41	20.8±0.48	5.8*	17.9[a]	15.3±0.48	21.5±0.87	6.2*	18.4[a]
Mean	13.3	17.4	4.1*		12.7	17.9	5.2*	
$LSD_{0.05}$ [(4)]	1.5				1.7			

[(1)]Faba bean (*Vicia faba* L.) seeds were planted on Oct 29th and 30th in the first and second years, respectively and the mushroom intercrop was placed within faba bean plants on Jan 1st (at flowering/pod setting), Jan 15th (at pod setting/early seed filling) and Jan 30th (at pod development/seed filling). [(2)] Star donates significant difference, at 0.05 probability level, between two means of mushroom cultivars when placed within faba bean plants of the same developmental stage. [(3)] Means for plant developmental status of faba bean, at the time of the mushroom intercrop placement, averaged over the two mushroom cultivars followed by the same letter are not significantly different at 0.05 probability level. [(4)] To compare two means of plant developmental stage of faba bean as affecting the same intercropped mushroom cultivar pinheads appeared earlier when grown under conditions of the placement within faba bean plants at flowering/pod setting or pod setting/early seed filling stages. Pinheads of *P. columbinus* mushroom did not significantly differ with regard to the days lapsed to their appearance whether grown under condition of placement at flowering/pod setting or pod setting/early seed filling stages in the first year. However, growing this mushroom cultivar under conditions of placement at flowering/pod setting in the second year produced earlier to appear pinheads. Apparently, both mushroom species were significantly late to produce visible pinheads in the two years under the conditions of intercropping within faba bean during pod development/seed filling stage.

The basidiocarp number, average weight and yield (Table 2-4) were affected by mushroom cultivar ($F_{1,15} = 12.4$; $p<0.05$, $F_{1,15} = 738$; $p<0.05$ and $F_{1,15} = 456.2$; $p<0.05$, respectively in the first year) ($F_{1,15} = 12.1$; $p<0.05$, $F_{1,15} = 473$; $p<0.05$ and $F_{1,15} = 364.6$; $p<0.05$, respectively in the second year), faba bean stage of development at the placement time for mushroom (flowering/pod setting, pod setting/early seed filling and pod development/seed filling stages) ($F_{2,15} = 6.9$; $p<0.05$, $F_{2,15} = 22.3$; $p<0.05$ and $F_{2,15} = 23.3$; $p<0.05$, respectively in the first year) ($F_{2,15} = 85.5$; $p<0.05$, $F_{2,15} = 23.3$; $p<0.05$ and $F_{2,15} = 70.2$; $p<0.05$, respectively in the second year) and their interaction ($F_{2,15} = 58.6$; $p<0.05$, $F_{2,15} = 25.3$; $p<0.05$ and $F_{2,15} = 137.3$; $p<0.05$, respectively in the first year) ($F_{2,15} = 32.1$; $p<0.05$, $F_{2,15} = 8.5$; $p<0.05$ and $F_{2,15} = 20.7$; $p<0.05$, respectively in the second year). Basidiocarp yield of *P. ostreatus* mushroom significantly surpassed that of *P. columbinus* in all placement treatments in both years (Table 2). The increase for placement at flowering/pod setting stage was 285% in the first year and 135% in the second year, respectively. Placement at pod setting/early seed filling stage showed an increase of 26 and 35% in the first and second years, respectively. The elevated basidiocarp yield was 32 and 43% for placement at pod development/seed filling stage in the first and second years, respectively. Clearly, the high basidiocarp yield produced by intercropped *P. ostreatus* mushroom placed at flowering/pod setting stage was accompanied by producing significantly larger number of basidiocarps and greater average weight of the basidiocarps (Table 3 and 4). The data for these latter two parameters were

Table 2: Total basidiocarp yield of two cultivated mushroom species (*Pleurotus ostreatus* and *P. columbinus*) interplanted with faba bean (*Vicia faba* L.) plants in the open field at three different stages of the faba bean plant development in 2008/2009 and 2009/2010[1]

Developmental status of faba bean plants at intercropping time	Mushroom cultivar (*Pleurotus* spp.)							
	2008/2009				2009/2010			
	P. ostreatus	*P. columbinus*	Diff.[2]	Mean[3]	*P. ostreatus*	*P. columbinus*	Diff.[2]	Mean[3]
Flowering/pod setting	56.18±0.89	14.56±1.07	41.62*	35.37[b]	41.50±1.04	17.69±1.12	23.81*	29.60[c]
Pod setting/early seed filling	44.20±1.65	35.14±1.17	9.07*	39.68[a]	47.97±1.25	35.56±1.55	12.41*	41.77[a]
Pod development/seed filling	36.35±1.28	27.50±0.89	8.85*	31.93[c]	40.55±1.38	28.38±1.47	12.17*	34.47[b]
Mean	45.58	25.73	19.85*[3]		43.34	27.21	16.13*	
$LSD_{0.05}$[4]	3.43				3.12			

[1]Faba bean (*Vicia faba* L.) seeds were planted on Oct 29th and 30th in the first and second years, respectively and the mushroom intercrop was placed within faba bean plants on Jan 1st (at flowering/pod setting), Jan 15th (at pod setting/early seed filling) and Jan 30th (at pod development/seed filling). [2]Star donates significant difference, at 0.05 probability level, between two means of mushroom cultivars when placed within faba bean plants of the same developmental stage. [3]Means for plant developmental status of faba bean, at the time of the mushroom intercrop placement, averaged over the two mushroom cultivars followed by the same letter are not significantly different at 0.05 probability level. [4]To compare two means of plant developmental stage of faba bean as affecting the same intercropped mushroom cultivar

Table 3: Number of basidiocarps for two cultivated mushroom species (*Pleurotus ostreatus* and *P. columbinus*) interplanted with faba bean (*Vicia faba* L.) plants in the open field at three different stages of the faba bean plant development in 2008/2009 and 2009/2010[1]

	Mushroom cultivar (*Pleurotus* spp.)							
	2008/2009				2009/2010			
Developmental status of faba bean plants at intercropping time	*P. ostreatus*	*P. columbinus*	Diff.[2]	Mean[3]	*P. ostreatus*	*P. columbinus*	Diff.[2]	Mean[3]
Flowering/pod setting	10.3±0.19	5.1±0.32	5.2*	7.7^b	8.1±0.11	6.2±0.26	1.9*	7.2^c
Pod setting/early seed filling	8.0±0.39	9.9±0.28	1.9*	8.9^a	8.9±0.01	9.5±0.11	0.6*	9.2^a
Pod development/seed filling	7.9±0.36	8.3±0.37	0.4us	8.1^b	8.8±0.18	8.8±0.28	0.0us	8.8^b
Mean	8.7	7.8	0.9us[3]		8.6	8.2	0.4*[3]	
$LSD_{0.05}$ [4]	1.0				0.5			

[1]Faba bean (*Vicia faba* L.) seeds were planted on Oct 29th and 30th in the first and second years, respectively and the mushroom intercrop was placed within faba bean plants on Jan 1st (at flowering/pod setting), Jan 15th (at pod setting/early seed filling) and Jan 30th (at pod development/seed filling). [2]Star donates significant difference, at 0.05 probability level, between two means of mushroom cultivars when placed within faba bean plants of the same developmental stage. [3]Means for plant developmental status of faba bean, at the time of the mushroom intercrop placement, averaged over the two mushroom cultivars followed by the same letter are not significantly different at 0.05 probability level. [4]To compare two means of plant developmental stage of faba bean as affecting the same intercropped mushroom cultivar

Table 4: Average basidiocarp weight of two cultivated mushroom species (*Pleurotus ostreatus* and *P. columbinus*) interplanted with faba bean (*Vicia faba* L.) plants in the open field at three different stages of the faba bean plant development in 2008/2009 and 2009/2010[1]

	Mushroom cultivar (*Pleurotus* spp.)							
	2008/2009				2009/2010			
Developmental status of faba bean plants at intercropping time	*P. ostreatus*	*P. columbinus*	Diff.[2]	Mean[3]	*P. ostreatus*	*P. columbinus*	Diff.[2]	Mean[3]
Flowering/pod setting	5.45±0.10	2.94±0.02	2.51*	4.20^b	5.10±0.11	2.86±0.07	2.24*	3.98^b
Pod setting/early seed filling	5.53±0.06	3.56±0.12	1.97*	4.55^a	5.38±0.14	3.75±0.18	1.63*	4.57^a
Pod development/seed filling	4.62±0.10	3.34±0.08	1.28*	3.98^c	4.69±0.07	3.23±0.7	1.46*	3.96^b
Mean	5.2	3.28	1.92*[3]		5.06	3.28	1.78*[3]	
$LSD_{0.05}$[4]	0.26				0.30			

[1]Faba bean (*Vicia faba* L.) seeds were planted on Oct 29th and 30th in the first and second years, respectively and the mushroom intercrop was placed within faba bean plants on Jan 1st (at flowering/pod setting), Jan 15th (at pod setting/early seed filling) and Jan 30th (at pod development/seed filling). [2]Star donates significant difference, at 0.05 probability level, between two means of mushroom cultivars when placed within faba bean plants of the same developmental stage. [3]Means for plant developmental status of faba bean, at the time of the mushroom intercrop placement, averaged over the two mushroom cultivars followed by the same letter are not significantly different at 0.05 probability level. [4]To compare two means of plant developmental stage of faba bean as affecting the same intercropped mushroom cultivar

as much as the double (200%) for *P. ostreatus* comparing with *P. columbinus* mushroom in the first year. The same was in the second year for average fruit weight while the number of fruit was only 32% larger. Placement at pod setting/early seed filling stage showed a marginal but significant decrease in the number of basidiocarps for *P. ostreatus* mushroom comparing with *P. columbinus* mushroom. However, average basidiocarp weight remained showing a magnificent significant increase in *P. ostreatus* mushroom (55 and 43% in the first and second years, respectively). Placement at pod development/seed filling stage showed no differences between the two cultivated species concerning the number of basidiocarps. On the other hand, average fruit weight continued to be greater for *P. ostreatus* mushroom (38 and 45% in the first and second years, respectively). The highest basidiocarp yield for *P. ostreatus* mushroom was produced when placed within faba bean plants at flowering/pod setting stage in the first year but at pod setting/early seed filling in the second year. The *P. columbinus* mushroom consistently had its highest basidiocarp yield when placed at pod setting/early seed filling. Obviously, basidiocarp yield for placement at pod development/seed filling stage was inferior to the other two placement treatments. No difference was detected in dry seed yield of faba bean whether grown with *P. ostreatus* or *P. columbinus* ($F_{1,15} = 0.162$; $p>0.05$) at any placement treatments ($F_{2,15} = 0.2158$; $p>0.05$). The faba bean with mushroom cultures placed between its plants produced an average dry seed yield estimated by 4057.1±26.3 kg ha^{-1}. Those faba bean grown as sole crop had lower ($t = 17.13$; $p<0.05$; $n = 6$) dry seed yield that was estimated to be 3191.08±43.2 kg ha^{-1}. This is about 27% increase in dry seed yield of faba bean.

Mushroom biological efficiency was affected by mushroom cultivar ($F_{1, 15} = 455.6$; $p<0.05$ and $F_{1, 15} = 364.5$; $p<0.05$ in the first and second years, respectively), faba bean stage of development at the placement time for mushroom (flowering/pod setting, pod setting/early seed filling and pod development/seed filling stages) ($F_{2, 15} = 23.2$; $p<0.05$ and $F_{2, 15} = 70.1$; $p<0.05$ in the first and second years, respectively) and their interaction ($F_{2, 15} = 137.1$; $p<0.05$ and $F_{2, 15} = 20.7$; $p<0.05$ in the first and second years, respectively) in both years of the study (Table 5). Biological efficiency of *P. ostreatus* mushroom was significantly higher than *P. columbinus* for all placement treatments (Table 5) in both years of this study. For placement of mushroom in faba bean field at flowering/pod setting stage, biological efficiency of *P. ostreatus* mushroom was as much as 286 and 135% higher than *P. columbinus* in the first and second years, respectively. The differences were diminished to 26 and 35% in the first and second year, respectively when placed within faba bean plants at pod setting/early seed filling stage. Placement at the pod development/seed filling stages resulted in 32% (in the 1st year) and 43% (in the 2nd year) increase in the biological efficiency. Growing

Table 5: Biological efficiency percent of two cultivated mushroom species (*Pleurotus ostreatus* and *P. columbinus*) inter-placed within faba bean (*Vicia faba* L.) plants in the open field at three different stages of the faba bean plant development in 2008/2009 and 2009/2010[(1)]

	Mushroom cultivar (*Pleurotus* spp.)							
	2008/2009				2009/2010			
Developmental status of faba bean plants at intercropping time	*P. ostreatus*	*P. columbinus*	Diff.[(2)]	Mean[(3)]	*P. ostreatus*	*P. columbinus*	Diff.[(3)]	Mean[(2)]
Flowering/pod setting	44.9±0.71	11.7±0.85	33.2*	28.3[b]	33.2±0.84	14.2±0.89	19.0*	23.7[c]
Pod setting/early seed filling	35.4±1.32	28.1±0.94	7.3*	31.7[a]	38.4±1.00	28.5±1.24	9.9*	33.5[a]
Pod development/seed filling	29.1±1.07	22.0±0.71	7.1*	25.6[c]	32.4±1.11	22.7±1.18	9.7*	27.6[b]
Mean	36.5	20.6	15.9*		34.7	21.8	12.9*	
$LSD_{0.05}$[(4)]	2.7				2.5			

[(1)]Faba bean (*Vicia faba* L.) seeds were planted on Oct 29th and 30th in the first and second years, respectively and the mushroom intercrop was placed within faba bean plants on Jan 1st (at flowering/pod setting), Jan 15th (at pod setting/early seed filling) and Jan 30th (at pod development/seed filling). [(2)]Star donates significant difference, at 0.05 probability level, between two means of mushroom cultivars when placed within faba bean plants of the same developmental stage. [(3)]Means for plant developmental status of faba bean, at the time of the mushroom intercrop placement, averaged over the two mushroom cultivars followed by the same letter are not significantly different at 0.05 probability level. [(4)]To compare two means of plant developmental stage of faba bean as affecting the same intercropped mushroom cultivar

Table 6: Cost of production, gross and net returus and benefit: production cost ratio for mushroom (*Pleurotus ostreatus*) faba bean (*Vicia faba* L.) intercropping (1)

Treatments	Capital cost (USD ha^{-1})	Gross return (USD ha^{-1})	Net return (USD ha^{-1})	Benefit: Production cost ratio
Outdoor intercrop and indoor cultivated mushroom				
Outdoor intercropped mushroom(2)	3,393.1	6,326.10	2,933.0	1:0.86
Outdoor intercropped mushroom(3)	3,393.1	5,970.60	2,577.5	1:0.76
Outdoor intercropped mushroom(4)	3,393.1	4,979.80	1,586.7	1:0.47
Indoor produced mushroom(5)	3,988.1	8,224.50	4,236.4	1:1.06
Iutercropped mushroom+faba bean				
Intercropped mushroom+faba bean(2)	5,435.9	11,735.4	6,299.5	1:1.16
Intercropped mushroom+faba bean(3)	5,435.9	11,379.9	5,944.0	1:1.09
Intercropped mushroom+faba bean(4)	5,435.9	10,389.9	4,953.2	1:0.91
Mouocropped and intercropped faba bean				
Monocropped faba bean	2,042.8	4,254.70	2,211.8	1:1.08
Intercropped faba bean(2), (3) and (4)	2,042.8	5,409.30	3,366.5	1:1.65

(1)Pooled data for 2 years; faba bean (*Vicia faba* L.) seeds were planted on Oct 29th and 30th in the first and second years, respectively. (2)Mushroom was placed within faba bean plants at flowering/pod setting. (3)Mushroom was placed within faba bean plants at pod setting/early seed filling. (4)Mushroom was placed within faba bean plants at pod development/seed filling. (5)Data form work with the same mushroom and substrate conducted by the authors under laboratory conditions (Mohamed *et al*., 2012a)

P. ostreatus mushroom intercrop at flowering/pod setting stage showed the highest biological efficiency as compared to the other placement treatments (27 and 55% over the placement at pod setting/early seed filling and pod development/seed filling stages, respectively) in the first year. In the second year, however, such result was obtained for mushroom placed within faba bean plants at pod setting/early seed filling stage. Consistently, *P. columbinus* mushroom demonstrated the highest biological efficiency for placement on the second date. The elevation of biological efficiency for the placement at pod setting/early seed filling stage ranged from 25-141% relative to the placement at flowering/pod setting and the placement at pod development/seed filling stages in the two years.

Costs and returns are estimated for production of oyster mushroom (*Pleurotus ostreatus*) (Table 6) since it was shown to be superior to *P. columbinus* oyster mushroom. Higher costs are shown (Table 6) for indoor production relative to outdoor production for oyster mushroom (*Pleurotus ostreatus*). However, indoor cultivation can give appreciable net returns that are reflected in 20% elevated benefit. Outdoor intercropping of *P. ostreatus* mushroom (Table 6) shows 10 and 3% increased benefit when placed in faba bean field at flowering/pod setting and pod setting/early seed filling stages, respectively comparing with indoor production. In addition, intercropping shows an increased benefit of 57% for faba bean crop.

DISCUSSION

Intensified cultivation system is thought to be one of the feasible strategies enabling maximized crop production. In this regard, interplanting of oyster mushroom with faba bean seems to hold a great promise. On average, 2326 and 2195 kg ha^{-1} fresh mushroom basidiocarp yield can additionally be produced in faba bean field when intercropping *P. ostreatus* mushroom at flowering/pod setting and pod setting/early seed filling stages, respectively. Interestingly, faba bean yield of dry seeds increased by 27% in the mushroom/faba bean intercropping cultures. In the present study, plastic bags each containing 0.5 kg was utilized for production of oyster mushroom. Increasing the volume of the culture substrate would result in further elevation in the mushroom intercrop yield.

Although increasing crop outcome is the ultimate goal of every agricultural research and developed technology, sustainable utilization of resources should be in the attention. Here, competition for growth factors and antagonistic needs of cultural practices do not exist in the mushroom/faba bean intercropping. Oyster mushroom obtains its nutrient needs via decomposition of lignocellulosic substrates and no photosynthesis is operated. Thus although dim light is sought to enhance fructification (Poppe, 1974), oyster mushroom has no essential obligate requirement of light. Roots of oyster mushroom did not grow out of the culture substrate into the soil and therefore, no competition for nutrient elements exists in the mushroom/faba bean intercropping. Due to the lack of competition, negative effect of interplanting mushroom with faba bean is rationally not expected. Mushroom cultures were placed in faba bean field during flowering/pod set and seed filling stages during which the availability of moisture is the most crucial. Mushroom cultures were lightly irrigated daily to keep the substrate medium moistened. This may maintain moisture available for faba bean plants to develop seeds. Possibility subsists for a leak of nutrients that released by mushroom biodegradation of the substrate and other compounds such as antioxidants. Under such conditions, faba bean seed yield could be elevated.

Temperature is one of the major factors affecting pinhead formation and fruiting bodies development. In the life cycle of *Pleurotus* mushrooms there are two stages (Ahmed, 1995): The vegetative growth stage and the reproductive growth stage. Generally, some kinds of stimuli are needed for the shift from mycelial (vegetative) growth to the basidiocarp formation (reproduction) phase. Alterations of temperature, humidity, gas concentration, light and nutrient reserves and physical stimuli can induce such stimulation (Sohman *et al.*, 2011; Mohamed *et al.*, 2012a). Among them, a sharp temperature drop is the most effective for induction of and transition to fructification in most mushrooms (Kong, 2004; Shah *et al.*, 2004). While 22-28°C is suitable for spawn running, pinhead formation and maturity of basidiocarp are better performed at lower temperature (12-18°C) (Bhatti, 1984; Kong, 2004). Oyster mushrooms are produced the best under temperature conditions ranges from 10-18°C (Kong, 2004). As shown by meteorological data obtained for the experiment site, temperature rises while relative humidity decreases with the advent of March. Oyster mushroom cropping started 2-5 weeks after placement in the field and those intercropped with faba bean at pod development/seed filling stage produced their basidiocarps during March. At this time, faba bean plants proceed toward developing mature pods and show defoliation of old leaves. Thus mushroom cultures are subjected to direct sun rays and possible dryness. The present data clearly show that the intercropping at pod development/seed filling stage of faba bean growth was inferior to the two earlier ones (at flowering/pod setting and at pod setting/early seed filling).

Differential species and strains are also affecting the productivity of oyster mushroom. As mention by Kong (2004), fructification is induced by low temperatures ranging from 10-15°C in *P. ostreatus* and *P. eryngii* but fructification of *P. florida, P. sajor-caju, P. cornucopiae* and *P. cystidiosus* is less affected by the temperature. Herein, *P. ostreatus* mushroom was shown to be superior to *P. columbinus* mushroom. This may due to its adaptability to the temperature and other conditions prevailing during the present study (Ibekwe *et al.*, 2008). Indeed, one of the features of *P. ostreatus* mushroom is that it requires a low temperature treatment called "cold shock" to initiate primordia formation (Kong, 2004). The *P. ostreatus* mushroom, a wood-destroying fungus, is widespread in the temperate zones that can be found growing on trees in the forest and it may secrete enzymes more capable to degrade complex components of the lignocelluloses (Ball and Jackson, 1995; Martinez-Carrera *et al.*, 2000; Mohamed *et al.*, 2011).

Average basidiocarp yield of *P. ostreatus* mushroom produced indoor on rice straw (Mohamed *et al.*, 2012b) was 30% more than its highest yield that was produced here as intercrop placed at flowering/pod setting stage of faba bean growth. This could be attributed to the fluctuating outdoor environmental conditions. However, net returns from intercropped mushroom plus faba bean seemed to be more profitable due to the increase occurred in the dry seed yield of faba bean. In conclusion, this study suggests possible beneficial outdoor production of oyster mushroom as intercrop with faba bean. The *P. ostreatus* mushroom is recommended to be placed in the field during flowering/pod setting to pod setting/early seed filling growth stages of faba bean.

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