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Maize yield response to crop rotation, farmyard manure and inorganic fertilizer application in Western Ethiopia

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Continuous cropping with inorganic inputs has limitations in terms of maintaining long-term soil fertility. However, crop rotation integrated with fertilizer application is one of the cheapest alternative methods for sustainable crop production. In recognition of this fact, the experiment was conducted at Bako in western Ethiopia with the objective of identifying the best precursor crops and optimum integration of farm yard manure and inorganic fertilizer in a maize based rotation sequence. Two separate trials with different precursor crops were combined with three rates of organic manure and three rates of inorganic fertilizer NP_2O_5. The experimental design was 3×3×3 factorial arrangement in randomized complete block design in three replications. Inclusion of precursor crops markedly increased maize yield as compared to mono crops. The highest grain yield was obtained when haricot beans and Niger seed were the precursor crops. Application of 12 t ha^{-1} FYM after precursor crops resulted in grain yield of 9.3 t ha^{-1} and a marginal rate of return 225%. However, continuous incorporation of manure after precursor crops did not significantly (P>0.05) increase the yield. Application of 89/-35 kg ha^{-1} NP_2O_5 after legume maize rotation gave a grain yield and the highest marginal rate of return (236%). Haricot bean, Niger seed followed by application of either 12 t ha^{-1}FYM or 89-35NP_2O_5 kg ha^{-1} is a better option for sustainable maize production than continuous mono cropping. As conclusion, haricot bean, Niger seed and Soybean can be used as precursor crops with use of either 12 t ha^{-1} of FYM or 89/35 kg $ha^{-1}$$NP_2O_5$.

Key words: Crop rotation, organic and inorganic fertilizer, precursor crops, maize.

INTRODUCTION

Low soil fertility is one of the major factors limiting crop production and productivity in small holder maize based cropping systems in Ethiopia. Inorganic inputs fertilizers in continuous cropping systems have limited ability for long-term maintenance of soil fertility (Zaman Allah et al., 2007). On the other hand, judicious application of crop rotation is a one of the cheapest methods for sustainable crop production. Legume-cereal sequence is one of the cropping pattern practices on smallholder farmers' in western Oromiya (Asfaw et al., 1997). Crop rotation sequences incorporating legumes can be used to effectively restore, maintain, enhance soil fertility and built up the N status of the soil (Yamoah et al., 1998). Rao and Mathuva (2000) stated that maize crops following annual legumes were 32 to 49% more profitable than continuous maize. Besides, reduced dependence on

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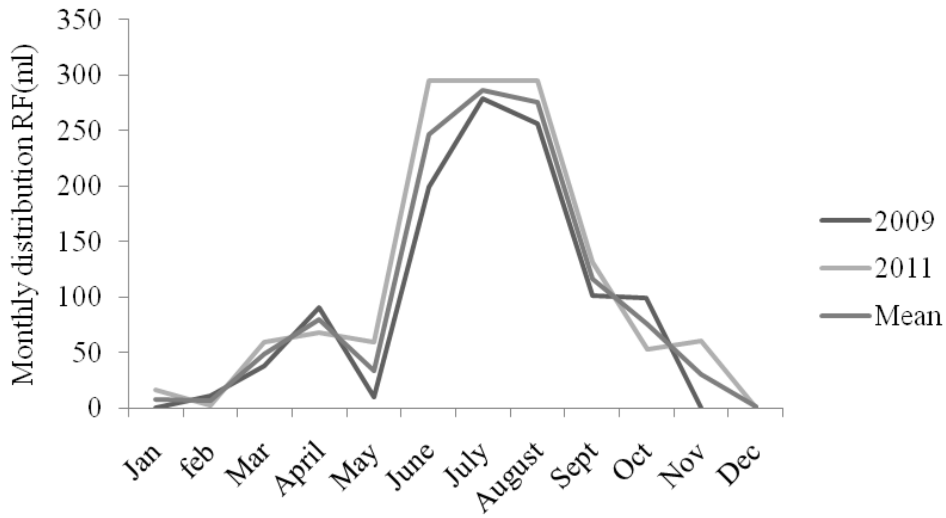

Figure 1. Monthly rain fall distributions during experimental cropping season at Bako.

chemical fertilizers crop rotations that favour nitrogen fixation will benefit both agriculture and environment and should be integrated in cropping systems (Zaman Allah et al., 2007).

Integrated use of organic and inorganic fertilizers is much better than single use of either chemical fertilizer or organic ones in maize cropping systems. It increases fertilizer use efficiency, reduces risks of acidification, and provides a more balanced supply of nutrients (Tolessa and Friesen, 2001). Organic manures and residue also improve physical and chemical properties of soil and fertilizer use efficiency when applied in combination with mineral fertilizers (Azraf-ul-Haq et al., 2007; Nalatwadmath et al., 2003). The objective of this study was to determine the effect of different precursor crops and subsequent application of integrated farm yard manure and inorganic fertilizer rates on maize yield and yield components of maize.

MATERIALS AND METHODS

The experiment was conducted at Bako Agricultural research Center in western Ethiopia located at latitude 9° 6' N; longitude of 37° 9' E and at an altitude of 1650 m above sea level. The site has a warm humid climate with annual mean minimum and maximum air temperature of 13.5 and 29.7°C, respectively. The area receives average annual rainfall of 1237 mm with maximum precipitation being received in the months of May to August. The soils at the experimental site are Nitosols.

The experiment was conducted in four consecutive years. The experimental plots were planted with the various precursor crops in the first year (2008) and third year (2010) while in second year (2009) and fourth year (2011) maize was planted under various fertilization regimes comprising of inorganic fertilizers and farm yard manure. The annual rain fall in 2009 (1080 mm) maize cropping season was lower than in 2011(1333 mm), which may also cause seasonal variation on crop yield though the distribution showed similar trends (t value=0.68) (Figure 1).

Treatment and experimental design

Two trials were conducted. In trial one, three precursor crops *viz.* Noug *(Guizoitia abyssinica)*, Soybean (*Glycine max*) without strain inoculation and Bush type of haricot bean (*Phasiolus vulgaris*) were grown in combination with FYM at 8, 12 and 16 t ha^{-1} and NP_2O_5 at 59-23, 89-35 and 110-46 NP_2O_5 kg ha^{-1}, where as in trial two there were another different precursor crops with the same combination of fertilizer rates. The design of the experiment was 3×3×3 factorial arrangement in randomized complete block design plus one farmer's practice in three replications. Farmers' practice was continuous cultivation of maize on the same plot year after year by using only chemical fertilizer. In trial two, the precursor crops were Tef (*Eragrostist tef*), climbing type of haricot bean and Soybean with ryzobium strain (TAL-378) inoculation. Permanent experimental plots measuring 4.5 m by 5.1 m were established in first year such that every precursor crops and fertilizer treatments were applied as per treatment arrangements. Soybean and haricot bean was planted in row arrangement with inter and intra row spacing of 40 cm and 10 cm, respectively. However, both Tef and Noug were broadcasted. All other management practices were applied as per their recommended agronomic practices. A mono cropping practice with recommended NP_2O_5 was planted on permanent plot in every year. All biomass of the precursor crops were retained on each plot and mixed with the soil during cultivation practices.

In the second (2009) and fourth year (20011), the experimental plots were manually cultivated starting at the onset of rain fall (in mid April to May). Well decomposed farm yard manure (20% moisture content), was applied three weeks before maize planting. The manure was uniformly distributed on each plot and thoroughly mixed with the soil. UREA and DAP were applied in prepared rows before time of planting. Urea was applied in two equal splits at planting and at knee height stage. Maize variety BH-660 variety was planted in late May for both trials. The inter and intra row spacing were 75 and 30 cm, respectively. All other management practices other than treatment variations were uniformly applied to the experimental plots.

Data were collected on plant height (cm), number of cobs per hectare, grain yields (ton ha^{-1}) and thousand grain weights (g). The three middle rows of maize which were harvested in the last week of November. All data were collected and subjected to analysis of variances procedure using Gen-Stat version-3. Treatment means

Table 1. The effect of precursor crops and subsequent application of integrated manure and inorganic fertilizer on yield and yield traits of Maize at Bako, Western Ethiopia.

Treatment	Plant height (cm)	Usable ears (ha^{-1})	Grain yield ($t\ ha^{-1}$)	1000 seed weight (g)
Precursor crops				
Niger seed	308	47838	9.4	479
Soybean (no inoculation)	318	47047	8.5	449
Bush haricot bean	311	49601	10.1	467
LSD (P<0.05)	5.5	1820	0.42	23.6
FYM ($t\ ha^{-1}$)				
8	306	47963	9.1	460
12	315	47535	9.3	466
16	316	48987	9.5	470
LSD (P<0.05)	5.5	1820	NS	23.6
N/P_2O_5				
59/23	307	46550	8.4	446
89/35	315	47991	9.6	469
110/46	316	49991	8.9	481
LSD (P<0.05)	5.5	1820	0.42	23.6
CV (%)	6	10	12	13
Maize mono crops	**278**	**42375**	**8**	**418**
F-probability				
Year	NS	**	**	**
Rotational crop(RC)	*	**	**	*
FYM	**	NS	NS	NS
NP_2O_5	**	**	**	**
RC x FYM	NS	NS	NS	NS
RC x NP_2O_5	NS	NS	NS	NS
FYM x NP_2O_5	NS	NS	NS	NS
CPxFYM xNP_2O_5	NS	NS	NS	NS

LSD = Least significant differences; FYM = farm yard manure; $t\ ha^{-1}$= tons per hectare; CV = coefficient of variations; NS = not significant.

were separated using least significant difference (LSD) test at 5% probability level.

RESULTS AND DISCUSSION

Statistical analysis of variances revealed that cropping season had a significant effect on grain yield (Tables 1 and 2). Pooled analysis (P<0.05) of two years data also indicated that main effects of precursor crops with succeeding application of manure and inorganic fertilizer sources significantly affected on plant height, number of cobs per hectare, grain yield and thousand grain weight of maize. However, the interaction effects did not show any significant variations on the same traits.

Effect of cropping season

The yield was significantly higher in 2009 cropping season than 2011 (Figure 2) this may be attributed to variation in rainfall over the two years. Rain fall distribution was similar (t value= 0.68) in both years but higher rain fall was recorded between June and August in 2011 as compared to 2009 cropping season (Figure 1). This may have significantly affected the physiological growth and development of the crops, and hence the yield difference. Similar result was also reported by Tolera et al. (2005) that cropping season significantly affected yield of maize.

Effect of precursor crops and fertilizer rates yield traits of maize

Plant height

The result revealed that higher plant height was recorded when inoculated or non inoculated soybean varieties were used as the precursor crops. These results are in agreement with the reported by Maheshbabu et al. (2008) who noted that higher atmospheric nitrogen fixation might

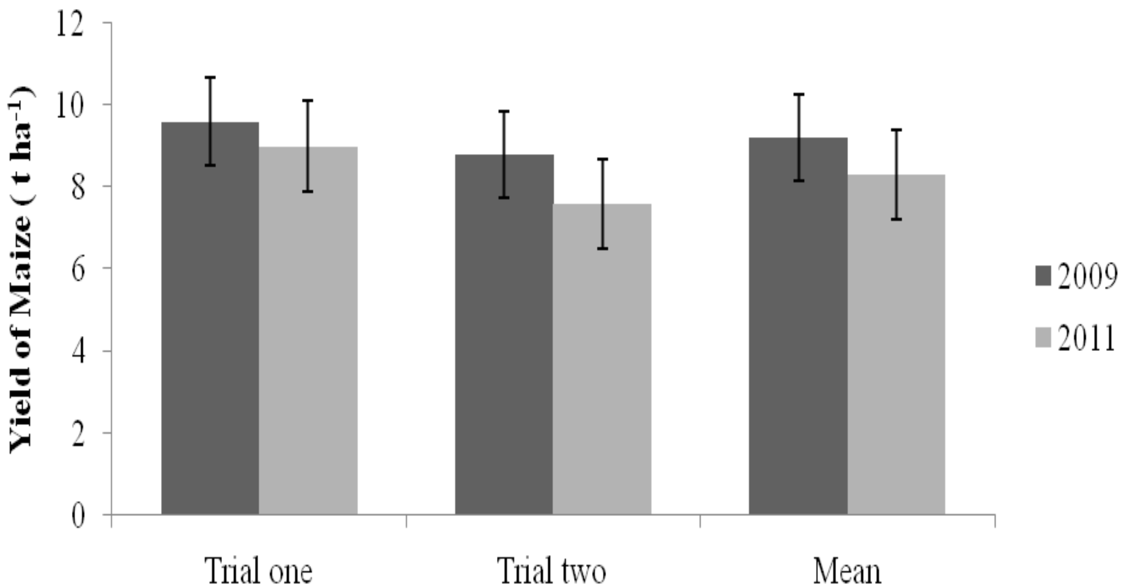

Figure 2. The effect of cropping season on grain yield of maize (bars indicate value of standard error means= 0.17; 0.16 for trial one and two, respectively; df=106; n=81).

lead to increase residual N in the soil. The lowest maize plant height was recorded when maize was rotated with Niger seed or Tef, indicating that both crops did not add nitrogen to the soil as that of legume crops.

An increase in plant height was observed as the function of increasing both FYM and NP_2O_5 application (Tables 1 and 2). The result also revealed that continuous mono cropping practices significantly reduced the height of the main crop when compared to the practice of crop rotation integrated with fertilizer application. About 10 to 14% increments were due to main effects of precursor crops and subsequent fertilizer application over mono cropped maize.

Usable ears per hectare

The result indicated considerable variation in the main effects of precursor crops, organic and inorganic fertilizer rates considerably on number of healthy cobs as compared to farmers' practices. The highest numbers of cobs were recorded when both bush and climbing types of haricot beans were used as precursor crops. The increase in number of cobs was 11 to 17% over yield of the mono cropped. This might be due to a higher contribution of legume crops in nutrient improvement most probably through biological nitrogen fixation or retention of residue in the soil (Agbede et al., 2008). Similar to precursor crops, main effects of both organic and inorganic fertilizer rates significantly ($P<0.05$) affected on number of cobs as compared to mono cropping practices. There was an increase trends in number of cobs as the function of increasing both rates of either manure or inorganic fertilizer (Tables 1 and 2).

Grain yield

The effects of precursor crops significantly affected grain yield of main crop. Both bush (10.1 t ha^{-1}) and climbing type (8.6 t ha^{-1}) of haricot bean showed the highest yield as compared to other precursor crops (Tables 1 and 2). Contrarily, the minimum yield was obtained when both uninoculated and inoculated soybeans were rotated with maize even though higher plant height was recorded. Though Niger seed did not fix atmospheric nitrogen, its effects on maize yield was significantly better than soybean, which might probably improve better physico-chemical properties of the soil and even may improve the residual availability of the phosphorus that may increase grain filling of main crop (Tolera et al., 2005).

Mono cropping practice revealed significant yield reduction when judged against yield obtained after main effect of precursor crops. About 9 to 35% yield advantage of maize was realized due to crop rotation practices over yield of mono cropped maize though climbing type of haricot bean gave the highest yield benefit which is in agreement with other authors (Yusuf et al., 2009b). This climbing haricot bean produced higher biomass as compared to bush one since it was supported by dry stake that may enhance maximum biomass production and hence improve soil fertility. Planting of maize after Tef was significantly better than planting of the same crop on the same plot year after year (Table 2). This result indicates that mono cropping practice may cause nutrient depletion, pest infestation and even may decline both

Table 2. The effect of precursor crops and subsequent application of integrated manure and inorganic fertilizer on yield and yield traits of Maize at Bako, Western Ethiopia.

Treatment	Plant height (cm)	Usable ears (ha^{-1})	Grain yield (t ha^{-1})	1000 seed weight (g)
Precursor crops				
Tef	308	48136	8.2	425
Climbing bean	306	50254	8.6	427
Soybean (TAL-378)	316	47785	7.8	408
LSD (P<0.05)	7.1	2093	0.4	15
FYM (t ha^{-1})				
8	306	46877	7.7	422
12	309	49504	8.4	418
16	312	49794	8.5	419
LSD (P<0.05)	7.1	2093	0.4	NS
NP_2O_5 (kg ha^{-1})				
59/23	306	48100	7.8	417
89/35	309	48711	8.2	429
110/46	315	49334	8.5	414
LSD (P<0.05)	7.1	2093	0.4	NS
CV (%)	6	11	13	11
Maize mono crops	**312**	**45095**	**7.0**	**390**
F-probability				
Year	NS	**	**	**
Rotational crop (RC)	**	*	**	*
FYM	NS	*	**	NS
NP_2O_5	*	NS	**	NS
RC x FYM	NS	NS	NS	NS
RC x NP_2O_5	NS	NS	NS	NS
FYM xNP2O5	NS	NS	NS	NS
CRxFYMxNP2O5	NS	NS	NS	NS

LSD = Least significant differences; FYM = farm yard manure; t ha^{-1} = tons per hectare; CV = coefficient of variations; Maize (NP2O5) = maize mono cropping practices under recommended inorganic fertilizer rates, * ,**= significant at 0.05 and 0.01 probability level respectively.

chemical and physical properties of the soil which might result in low yield (Yusuf et al., 2009a, b).

The result of pooled means over years also revealed in trial two that application of organic manure after precursor crops had a significant effect on yield of maize, but not in trial one (Tables 1 and 2). Application of FYM year after year on the same farm did not significantly increase the yield (Figure 3). This result with other finding indicated that nutrient availability may increase after one or two years as the decomposition rate may be enhanced than at initial time of manure application (Rao and Mathuva, 2000; Maheshbabu et al., 2008).The lowest yield was obtained when the lowest rate (8 t ha^{-1}) of FYM was applied. Comparing to yield of maize mono crops, about 14 to 19% (Table 1) and 10 to 21% (Table 2) yield advantage was obtained due to main effect of manure application.

Yield increased considerably as the rate of inorganic fertilizer was increased. The maximum yield was obtained when 110/46 kg ha^{-1} NP_2O_5 was applied though not significant from 89/35 kg ha^{-1} NP_2O_5). Yields were significantly lower under mono cropping as compared to different rate of inorganic fertilizer (Tables 1 and 2).

Thousand seed weight

The main effect of precursor crops, manure and NP_2O_5 application were showed significant effect on thousand seed weight except in trial two (Tables 1 and 2). Rotation of maize with haricot bean and Niger seed significantly increased seed weight. Moreover, there was an increase

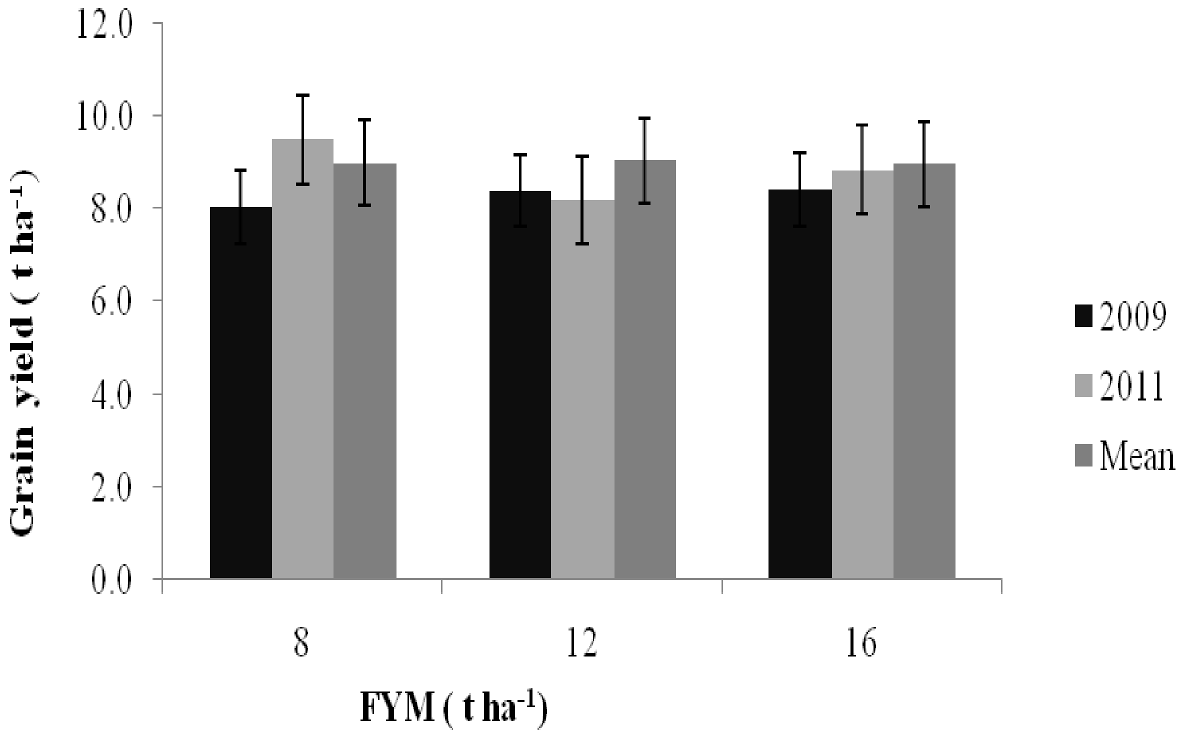

Figure 3. The effect of FYM application on grain yield of maize across the years at Bako, Western Ethiopia (bars indicate standard error of difference=0.29, df=106; n=27).

trends in seed weight as FMY and inorganic fertilizer rates increased though organic manure did not significantly vary (Table 2).

Marginal rate of return and net benefit

The result of partial budget analysis revealed that application of 12 t ha^{-1} FYM and 110/46 N/P_2O_5 gave the highest net benefit. However, the highest marginal rate of return (MRR) was obtained when 89/35 NP_2O_5 kg ha^{-1} and 12 t ha^{-1} FYM were applied (Table 3). In other words, use of 89/35 N P_2O_5 kg ha^{-1} gave 2.36 ETH birr of return per one birr investment. Similarly, about 225% return was also gained when 12 t ha^{-1} of FYM was applied as compared to other manure rate. Though an increase trends as the purpose of increasing both FYM and NP_2O_5 rates was observed in grain yield, uses of either 12 t ha-1 FYM or 89/35 NP2O5 kg ha^{-1} is economically optimum. However, continuous manure application would not be advisable since it was not significantly increase economic yield.

Conclusions

Though bush and climbing type of haricot bean highly increased the grain yield, using both Niger seed and soybean generally resulted in higher maize than under mono cropping practices. The effect of Niger seed on thousand seed weight was significant. Continuous mono cropping significantly reduced on yield and yield traits of maize as compared with the effect of precursor crops.

Similar to precursor crops, both FYM and inorganic NP_2O_5 fertilizer considerably varied on yield and yield traits of maize. However, application of FYM year after year on the same farm did not significantly increase the yield. This revealed that nutrient availability may increase through gradual decomposition. Manure application with 12 t ha^{-1} rate revealed optimum yield and net profit with the highest rate of return as compared to 8 and 16 t ha^{-1}. Similarly, 89/35 NP2O5 kg ha^{-1} was also revealed the highest marginal return and gave optimum yield. As a conclusion, uses of haricot bean, Niger seed and soybean as precursor crops with subsequent application of either 12 t ha^{-1} or 89/35 NP_2O_5 kg ha^{-1} is one of the best management options for sustainable maize production.

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Table 3. Partial budget and net benefit analysis for FYM and N_2O_5 on the mean grain yield of maize at Bako, Western Ethiopia.

Fertilizer source	**Growth return (ETH birr/ ha)**					
Item	**FYM (t ha^{-1})**			**NP_2O_5 (kg ha^{-1})**		
	8	**12**	**16**	**59/23**	**89/35**	**110/46**
Average yield (kg ha^{-1})	8400	8900	9000	8000	8900	9200
Adjusted yield (kg ha^{-1})	7560	8010	8100	7200	8010	8280
Gross field benefit (Eth/ha)	21168	22428	22680	20160	22428	23184
Cost that vary (ETH birr/ha)						
valued cost of manure	960	1440	1920	-	-	-
Cost of manure application	160	240	320	-	-	-
Cost of DAP	-	-	-	700	1065	1400
Cost of UREA	-	-	-	1174	1768	2160
Total cost that vary	1120	1680	2240	1874	2833	3560
Net benefit	20048	20748	20440	18286	19595	19624
MRR (%)	-	230	50	-	236	104

Grain price = EB 2.8 /kg, DAP/UREA = ETHB 14.0/10.80 per kg, Valued cost of manure = ETHB 120/ ton and labor cost for fertilizer application = ETHB 14 /day, Yield was down adjusted with 10% coefficient; 1 USD=17.68 ETH birr.

collect all necessary data.

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