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Comparative Evaluation of Horizontal and Vertical Frame Beehives at Adami Tulu Agricultural Research Center of Oromia, Ethiopia

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Abstract: The sole purpose of a hive is to encourage the bees to construct their nests in such a way that it is easy to manage and maintain them. The study was conducted at Adami Tulu Agricultural Research Center to evaluate the performances of honeybee colonies, honey yield and cost incurred in both horizontal beehives as compare to movable frame beehive. A total of 12 honeybee colonies (*Apis mellifera bandasii*) were established and assigned into four treatment groups. All the established honeybee colonies were managed in uniform manner until they are established properly and acquire uniform strength. Data on bee population, brood area, pollen and nectar stored areas were recorded using Liebefeld method (frame unit area, 10 x10 cm^2) at every 21 days. In addition, data on average honey yield per harvest/colony, production costs and profit were recorded for each treatment during the study period. All the recorded data were organized by Microsoft excel and analyzed using descriptive statistical analysis of variance ANOVA of SAS software version 20. Results revealed that there was statistically significant difference ($p<0.05$) between Tensheratach beehive, Modern beehive and Bacho beehive with regarding to honey yield. The highest mean honey yield per hive (24.81±3.24 kg/hive) was recorded from Tensheratach beehive followed by Modern beehive (21.51±2.36 kg/hive) and Bacho beehive (17.3±1.43 kg/hive). Significantly greatest adult bee population, brood area, pollen and nectar stored areas were also recorded from Tensharatech beehive compare to Modern beehive and Bacho beehive. The total costs of production and economic returns of Tensheratach beehive were higher than Modern beehive and Bacho beehive. From this study, it is possible to recommend that Tensheratach beehive can be used as an alternative beehive technology for honey production with full packages in addition to modern beehive.

Keywords: Honeybee, Hive Type, Brood Area, Production Cost, Honey Yield

1. Introduction

Beekeeping is one of the main sources of income for smallholder honey producing farmers of Ethiopia. It provides significant profit to address household's food security and poverty alleviation through income diversification for beekeepers in potential areas [5]. The existence of various agro-climatic zones resulted from the various topographic variations make the country suitable for many bee floras and huge number of bee colonies [13]. For the reason that, Ethiopia is one of the top 10 producers of honey in the world (china, Turkey, United states, Ukraine, Argentina, Mexico, Russian Federation, Iran, Ethiopia, and Brazil) and it is the largest one in Africa [17]. Despite of having the highest bee density and being the leading honey producer in Africa, the share of the sub-sector in the GDP has never been matched with the huge numbers of honey bee colonies and the country's potentiality for beekeeping. This is due to the traditional method of beekeeping practices which have great impact on the quantity and quality of honey.

Beekeeping has got many advantages for smallholder farmers of our country. It has great role in improving the well being of beekeepers. From the total honey produced in the country farmers are expected to get about 360-480 million

Birr/year [14]. The beekeeping farming is also important in creating job options in both rural and urban areas through organizing unemployed urban and landless rural youth and women to involve in them in beekeeping activities [6].

Ethiopian honey production is characterized by the widespread use of traditional technology, resulting in relatively low honey supply and poor quality of honey harvested when compared to the potential honey yields and quality gains associated with modern beehives. In Ethiopia, honey production remains traditional as 94 to 97% of bees are still kept in traditional hives [10]. Based on the stage of technical development three different types of beehives have been used for honey production in Ethiopia. These are traditional beehives, transitional beehive and movable frame beehives. A total of about 4,601,806 hives exist in the country of which about 95.5% are traditional, 4.3% transitional and 0.20% modern hives [3]. Based on the national estimate, the average yield of pure honey from movable frame hive is 15-20 kg/year and the amount of beeswax produced is 1-2% of the honey yield [7]. However, in potential areas, up to 50-60 kg of harvest has been reported [8].

To improve the livelihoods of rural people in Ethiopia, large numbers of improved hive technologies are in the progress of distribution to beekeepers with rich experience in beekeeping.

Movable frame hive was introduced to Ethiopia and being used for more than 50 years. Innovative beekeepers realized that this hive has a limitation like, while inspection, bees boiled out to the air as a result chance of being stung and consequently bee mortality are higher. Hussein Adam and Mohammed Fisaha beekeeper of Shashemene and Bacho district of Ilubabora zone respectively were modified the frame hive to minimize the problem prevailed in frame hive and they are using modified hives at present. The hives that these innovative beekeepers, Hussein Adam and Mohammed Fisaha have come up with are named Tensheratach and Bacho respectively. These hives are made of timber and have two compartments with two open doors, queen excluder and 25 rectangular frames. To improve productivity and production of honeybee products, selection and adoption of different improved beehives is highly essential. Though these modified beehives are being used by the owners, there was no study undertaken to evaluate the performances of these horizontal hives. Therefore this study was carried out to evaluate the performances of honeybee colonies and honey yield and cost incurred in both horizontal hives as compare to movable frame hive under Adami Tulu condition.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted at Adami Tulu Agricultural Research Center (ATARC), located at 167 km South of Addis Ababa at altitude 1650 above sea meter, latitude 17°9' N and longitude 38°7'E. The average annual rain fall is 760.9 with an average minimum and maximum temperature of 12.6°C and 27°C respectively [1].

2.2. Experimental Treatments

Three beehive types: namely Modern beehive, Tansheratach beehive and Bacho beehive were used as treatments for evaluation purposes (Figure 1). Modern beehives (Zander model) were manufactured at Jimma Agricultural engineering Research Center. Tansheratach and Bacho hives were purchased from Shashemene and Ilu-Ababor respectively. A total of 12 honeybee colonies (*Apis mellifera bandasii*) were established and assigned into four treatment groups. All the transferred colonies were managed in uniform manner until they are established properly and acquire uniform strength. Each beehive type was replicated four times.

2.3. Data Collected

Data such as adult bee population, brood area, pollen and nectar areas were recorded using Liebefeld method (frame unit area, 10 x 10 cm^2) at every 21 days [11]. Also, honey yield, production costs and gross return were taken. Before establishing of honeybee colonies, the size of bee space and hive entrance of each type of beehive were checked (Table 1).

Table 1. *The size of bee space and hive entrance of the three hive types.*

Type of hive	Bee-space (cm)	Hive entrance (cm)
Tensheratach	1	1x1
Modern	1	1x15
Bacho	1	1 x 12.3

(a) (b) (c)

Figure 1. *Vertical and horizontal frame hives used for comparison: a) Modern hive), b) Tensheratach hive, c) Bachohive.*

2.4. Rating the View Characteristics of Different Hive Types

Characteristic view after three years of keeping different type of hives were rated as excellent, very good, good, fair and poor.

2.5. Statistical Analysis

All the collected data were organized by Microsoft excel and analyzed using descriptive statistical analysis of variance ANOVA of SAS software version 20. Means were separated by using Tukey's honest significant difference (HSD) at 5% level of significance whenever significant results encountered between beehive types.

2.6. Cost and Benefit Analysis

The most important issue of the present study was to determine the type of beehive with better profit for better life of small scale beekeepers. It is involved the calculation of variable costs and benefits. For the calculation of the variable costs, the expenditures incurred on various production cost of beehive, inputs for honey production, honeybee colony purchase and protective clothes were taken into consideration. Finally, the selling price for a kg of honey in local market was assessed in the study areas. Net incomes (NI) were calculated as the amount of money left when total variable costs (TVC) subtracted from the total returns (TR).

$$NI = TR - TVC$$

3. Results and Discussion

3.1. Honey Yield

The results of the study indicated that there was statistically significant difference ($p<0.05$) between Tensheratach, Modern and Bacho hives with regarding to the average of honey yield per colony. The highest honey yield (24.81±3.24 kg/hive) was recorded from Tensheratach hive followed by Modern hive (21.51±2.36 kg/hive) and Bacho hive (17.3±1.43 kg/hive). This agrees with the study of [13, 18] who reported that the average annual honey yield of improved frame hives at national level was 20-25 kg/hive but, lower than [2] who reported that the average annual honey yield performance of improved frame hive was 30.09 kg/hive. The productivity of Tensheratach hive in this study is higher than that of Modern and Bacho hives could be due to high bee population found in Tensheratach beehive than that of Modern and Bacho hives because of the mean honey yield per colony was significantly affected by the population size of colonies. Strong bee colonies rear more brood and produce more honey than weak colonies because of strong colonies make longer flights and bring back to the hive significantly bigger loads of nectar compared to forager bees from weak colonies. This agrees with the study of [12] who reported that honey yield increases in line with the increasing number of bees in the colony relative to the amount of open brood. [16] also reported that the production of honey is significantly positively correlated with the number of brood cells only in the first half of the season.

3.2. Colony Evaluation Parameters

3.2.1. Sealed Worker Brood Area

Sealed worker brood area noted after 21 days intervals is presented in table 2. The results of the study indicated that the brood rearing activity was statistically significant difference ($p<0.05$) between Tensheratach, Modern and Bacho hives (table 2). The highest mean brood area (150.21±0.6/colony) was recorded from Tensheratach hive followed by modern hive (128.57±2.4/colony) and Bacho hive (86.33±2.1/colony). Significantly higher mean of brood area produced in Tensheratach hive could be due to high bee population found in Tensheratach hive than that of Modern and Bacho hives. Strong honeybee colonies make longer flights and bring back to the hive significantly bigger loads of pollen and produce more brood than weak colonies. This agrees with the study of [4] who reported that strength of bee colonies is significantly positively correlated with the amount of brood rear colonies. This result implies that a hive that encourages population growth will produce more brood and reduce honey consumption per bee during the dearth period [16].

3.2.2. Pollen Area

The result of the study indicated that there is statistically significant difference ($p<0.05$) between Tensheratach beehive, Modern beehive and Bacho hive. Significantly higher mean of pollen areas (112.35±6.1/colony) were recorded from Tensheratach hive as compared to Modern hive (75.22±3.6/colony) and Bacho hive (63.4±0.08). Significantly higher mean area of capped brood in Tensheratach hive could be due to the large bee population found in the Tensheratach hive than that of Modern and Bacho hives. Strong honeybee colonies make longer flights and bring back to the hive significantly bigger loads of pollen and tore. This agrees with the study of [15] who reported that pollen collected by strong colonies was higher.

3.2.3. Nectar Area

Nectar is an aqueous solution secreted from floras of plants profoundly containing sugars mainly glucose, fructose and sucrose with traces of minerals and proteins. The result of the study indicated that there is no statistically significant difference ($P>0.05$) between Tensheratach hive and Modern hive in nectar area. But there is statistically significant difference ($P<0.05$) between Modern hive and Bacho hive. Strong and healthy bee colonies stored more nectar as compared to weak colonies.

3.2.4. Adult Bee Population

The highest mean of adult bee populations (9.54±2.4) was found in the Tensheratach hive as compared to Modern hive (6.82±0.7) and Bacho hive (4.27±4.3). The reason for higher number of worker bees in Tensheratach hive could be explained by the relatively high mean sealed brood area because the sealed brood represents the next population of workers. This agrees with the study of [9] that showed that positive correlation was found between colony populations and sealed brood area.

3.2.5. Cost and Return Analysis of Different Hive Types

Total costs of production and gross return of Tensheratach hive was higher than other hive types (Tables 4 & 5).

Table 2. *Mean + SD of honey yield, adult bee population, brood area, pollen and nectar store areas of different beehive types.*

Hive type	Mean ±SD				
	Honey yield (kg/hive)	Brood area (cm^2)	Pollen area (cm^2)	Nectar area (cm^2)	No of comb covered by bees (cm^2)
Tensheratach	24.82±3.24[a]	150.21±0.6[a]	112.31±6.1[a]	125.2±4.6[a]	9.54±2.4[a]
Modern	21.51±2.36[b]	128.57±2.4[b]	75.22±3.6[c]	113.15±1.3[a]	6.82±0.7[b]
Bacho	17.3±1.43[c]	86.33±2.1[c]	63.4±0.08[b]	87.32±0.5[c]	4.27±4.3[c]

Means in a column having different superscript are statistically different at P<0.05.

Table 3. *Characteristic view after three years of keeping different beehive types.*

Parameters	Hive type			Verifiable indicators
	Tensheratach	Modern	Bacho	
Simplicity of hive management practice	5	5	5	1. Suitable for colony inspection and honey harvesting 2. Easy to control swarming 3. Possible to manage the volume of the hives according to the strength of colonies 4. Bee breeding and queen rearing is possible 5. Can be transported with bees from one place to another for migratory beekeeping practices.
Minimize of honeybee mortality rate	5	3	5	1. Tensheratach and Bacho hives have two chambers with two opening doors. 2. During colony inspection and honey harvesting, honeybee colony moved from first chamber to second chamber and return back to the first chamber. 3. Honeybee get enough space without moving outside 4. This is minimize the mortality rate of honeybee during inspection and honey harvest
Improve ventilation	5	4	3	1. Tensheratach and Modern hives are better to emit heat and moisture to rise up and out hive
Minimize of the infestation rate of pests and predators	4	2	2	1. Tensheratach hive has small hive entrance than Bacho and Modern hives 2. This can reduce colony invasion by pests and predators appears which adversely affect all aspects of beekeeping
Simplicity of honey harvesting	5	5	5	1. Easy to harvest honey 2. Honey extractor can be used without damaging the frame combs 3. Pure and standard honey can be harvested
Hive preference	5	4	3	1. Colony show better preference for Tensheratach hive and this could be due to the insulation nature of the hive

Score given: Excellent=5, Very good=4, Good=3, Fair=2, Poor=1.

Table 4. *Presentation of variable costs of each hive type.*

Major items	Hive type		
	Tensheratach	Modern	Bacho
Beeswax (Kg)	4500	4500	4500
Overall	1000	1000	1000
Smoker	200	200	200
Hand glove	180	180	180
Bee veil	300	300	300
Battery	100	100	100
Honeybee colony	2400	2400	2400
Feeding	300	300	300
Hive	8000	5900	6400
Total production cost	16980	15580	15380

Table 5. *Total variable costs and gross return of different types of hive owned 4 hives.*

Hive type	Total production cost (ETB)	Gross return (ETB)	Net income per beekeepers (ETB)	Net income per hive (ETB)
Tensheratach	16980	24820	7840	1960
Modern	15580	21510	5930	1483
Bacho	15380	17300	1920	480

Note: The price of pure honey per kg was 250 Ethiopian Birr.

4. Conclusion and Recommendations

The present results indicated that Tensheratach hive had better performance in terms of honey yield per hive, workers sealed brood area, pollen and nectar stored area, adult bee population and economic returns as compared to Modern beehive and Bacho beehive. Therefore, it is recommended to use Tensheratach beehive as an alternative technology with full packages in addition to Modern beehive. Bachohive has

some drawbacks from the scientific perspective; it is therefore recommended that, before promoting the Bachohive for wider uses some, modifications should be made to remove its weaknesses and, then, it should be tested with more replications in different areas so as to allow a better understanding and evaluation of the hive. Hive types have a great impact on colony performance and honey yield. Thus, further studies should be carried out to evaluate any new hive type using several parameters and different bee races.

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