Apicultural Research

A Comparison of Three Non-Migratory Systems for Managing Honey Bees (*Apis mellifera* L.) in Minnesota

Part I: Management and Productivity[1,2,3]

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ABSTRACT

The management practices and productivity of 3 treatments (package colonies, vertical 2-queen, and horizontal 2-queen) were compared on a 2-queen unit basis. Treatments (management systems) were compared at one location in 1986 and at 2 locations in 1987. There were no significant differences in queen acceptance among the treatments. Survival of queens in the vertical 2-queen treatment was significantly lower than in the package colony and horizontal 2-queen treatments. Significantly less brood area was found in the package colony treatment than in the vertical and horizontal 2-queen treatments in mid May. The combined main flow net productivity differed significantly among treatments, with the horizontal 2-queen treatment exhibiting the greatest weight gain.

INTRODUCTION

MANAGING HONEY bees for honey production has interested people for centuries. The advent of modern hives in the mid to late 1800's gave beekeepers more control over the activities of honey bee colonies, which in turn led to increased productivity.

Several non-migratory approaches to honey production have evolved in Canada and the north central United States. Among these, package colonies, overwintered colonies, and

Figure 1. One of the circles in Apiary II containing nine, 2-queen experimental units.

overwintered 2-queen colonies have all been used successfully.

Braun (1941) in Manitoba and Haydak (1950) in Minnesota both found that overwintered colonies produced more honey than did package colonies.

Many workers have reported that 2-queen colonies positioned vertically on a stand produced more honey than did single-queen colonies. In Wyoming, Farrar (1936, 1937) more than doubled the honey production from single-queen colonies by managing colonies with 2 queens. In an 8-year study, Farrar (1946) found honey production from 2-queen colonies exceeded that of single-queen colonies and single-queen package colonies. Moeller (1976) reported similar results in his comparison.

Haydak and Dietz (1967) and Walton (1974) found that 2-queen colonies produced more honey than did single-queen colonies. Other workers have used variations of Farrar's approach with success (Dunham, 1953; Holzberlein, 1953; Banker, 1968, 1975).

Braun (1935, 1945) demonstrated that strong overwintered colonies can be divided ('split') for replacement and increase. This concept was further developed into a perennial colony management system called the 'Horizontal 2-queen' system (Furgala and Sugden, 1980). In this system, colonies that overwinter (parents) are divided (divisions) in the spring. In the fall, parents are depopulated and the divisions are wintered. In this way the number of colonies is maintained year after year. Sugden and Furgala (1982a, 1983), Duff and Furgala (1986), and Sugden *et al.* (1988) have routinely divided their overwintered experimental colonies.

Although surplus honey yields from package colonies, overwintered colonies, and 2-queen colonies have been compared, researchers have not evaluated complete perennial honey bee management systems. This investigation was designed to compare management systems with 2 queens per experimental unit.

MATERIALS AND METHODS

General

This comparison of 3 treatments (management systems) was conducted in east central Minnesota. The experimental unit for each treatment included 2 laying queens during the buildup period. The first treatment consisted of two, 2-pound packages (2 PK) hived on 2 different hive stands. The second treatment consisted of a parent colony and its division on the same hive stand. This vertical 2-queen (V2Q) treatment was based on the adaptation by Banker (1975) of the management scheme of Farrar (1958). The third treatment consisted of a parent colony on the original stand and its division which was moved to a different hive stand. This horizontal 2-queen (H2Q) treatment followed techniques outlined by Furgala and Sugden (1980).

The colonies for the study were established at one location (Apiary I) in 1986 and at 2 locations (Apiaries II and III) in 1987.

In each of the 3 apiaries, a complete randomized block design was used. Each block consisted of hive stands arranged in circles. Treatment colonies were randomly assigned to the hive stand positions in each block. Each block contained three, 2-queen replications, totalling 18 queens and 15 stands (Fig. 1). There were 3 blocks in Apiary I and 4 blocks in Apiary II and Apiary III.

Management Practices — Apiary I — (1985-1986)

Colonies for the V2Q and H2Q treatments were established in circles during May 1985 at Apiary I. The colonies were managed during the summer of 1985 and were wintered in 3 deep Langstroth hive bodies. In early April 1986, 3 of the overwintered colonies with clipped and marked Starline queens were randomly assigned to the V2Q treatment in each block, and 3 similar colonies to the H2Q treatment in each block. Management practices and data collection began with the arrival of the packages in April 1986.

Package Colony Treatment (2PK)

In mid April 1986, the experimental 2 lb. packages were hived in deep hive bodies which contained darkened combs and approximately 8 lbs. of honey. The clipped and marked Starline queens were 'direct released.' Four additional packages were hived the same day in another location to be used as replacements for packages that experienced queen loss during the first 30 days. After this initial period, each experimental unit of the 2PK treatment consisted of 2 package colonies within the same block.

Package colonies were fed 1:1 (wt./wt.) medicated (95 mg fumagillin/gal.) sucrose syrup immediately after hiving. Feeding continued for about 6 weeks, or until natural nectar flows could support the colony. During this time, each package colony in the 2PK treatment experimental unit received 2.65 ga. of sucrose syrup. Each package colony received 4 applications of oxytetracycline hydrochloride (TM) mixed with powdered sugar prior to 1 June (Furgala, 1984).

Approximately 30 days after hiving, a second hive body containing drawn comb and 6 lbs. of honey was added to each colony. In late June, hive bodies were reversed. Medium depth honey supers with drawn comb were added as needed throughout the summer. The honey supers above the 2 hive bodies were removed in August. All 2PK treatment colonies were depopulated in late October.

Vertical 2-Queen Treatment (V2Q)

In late April 1986, the overwintered colonies assigned to the V2Q treatment consisted of 3 deep hive bodies and 2 medium depth honey supers with drawn comb. V2Q treatment colonies were divided in mid May 1986. Each V2Q treatment division containing approximately 800 sq. in. of brood and adhering bees was placed in one of the hive bodies. Each V2Q treatment parent colony remained on the original stand with the queen, remaining brood in the other 2 hive bodies, and the 2 honey supers. A double screen divider was placed above the parent colony and the division set above the double screen. Each V2Q treatment division was fed 0.7 gal. of 1:1 (wt./wt.) sucrose syrup and kept queenless for 2 days. After this time, a clipped and marked Starline queen in a mailing cage was introduced to the division. Queen acceptance was checked 6 days after introduction. A second queen was introduced if necessary.

V2Q treatment colonies received 6 treatments of TM and powdered sugar prior to 1 June (Furgala, 1984).

V2Q treatment colonies were examined 4 additional times (about every 10 days) prior to the main nectar flow. During the first examination, queens were checked, the 2 hive bodies of the parent reversed, and a hive body with 6 lbs. of honey added to the division. Honey supers remained with the parent, below the double screen.

During the second examination, the hive bodies of both parent and division were reversed. The double screen di-

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vider was replaced with a queen excluder, thereby keeping the 2 queens apart but allowing worker bees to mix.

The third examination included a reversal of the complete V2Q unit. The division was reversed and positioned on the bottom board, while the parent was reversed and elevated above the queen excluder.

The final examination was made at the end of June, just prior to the main nectar flow. At this time all 4 hive bodies were reversed, the queen excluder removed to allow free movement of bees and queens, and the honey supers placed above the hive bodies.

Adequate space was provided during the nectar flow. All honey supers were removed in August. In mid September, each V2Q treatment colony was dusted with TM and fed 2 gal. of 2:1 (wt./wt.) sucrose syrup containing 190 mg fumagillin. Each colony was left in 4 hive bodies, weighed with a spring scale, and fed additional medicated syrup until the gross colony weight reached 210 lbs. Each colony was prepared for winter using a commercial cardboard winter carton.

Horizontal 2-Queen Treatment (H2Q)

In late April 1986, the overwintered colonies assigned to the H2Q treatment consisted of 3 deep hive bodies and 2 medium depth honey supers. In mid May 1986, the H2Q treatment colonies were divided. Each H2Q treatment division containing approximately 800 sq. in. of brood and adhering bees was placed in one of the hive bodies. Each H2Q treatment parent remained on the original stand with the queen, the remaining brood in the other 2 hive bodies, and the honey supers. The H2Q division was removed from the parent colony stand and positioned on a vacant stand within the same block.

Introduction of queens and inspection to determine queen acceptance were performed as described for the V2Q treatment.

The hive bodies of the H2Q treatment parent colonies were reversed 4 additional times prior to the main nectar flow. Each parent received 5 TM applications prior to 1 June. Each H2Q division received a second hive body containing 6 lbs. of honey after the new queen had been accepted. A third drawn empty hive body was added to the division in early June. Each division was reversed at the end of June. H2Q divisions received 2 applications of TM prior to 1 June.

Honey supers were added to H2Q parents and divisions as needed. All honey supers were removed in August. Each parent colony was left with its original 2 hive bodies and was depopulated in late October. Each H2Q division was dusted with TM and prepared for winter in the same manner as described for the V2Q treatment colony, except the H2Q division had 3 hive bodies and a minimum post-feeding gross weight of 185 lbs.

Management Practices — Apiaries II and III — (1986-1987)

The treatments and procedures described above were repeated in Apiaries II and III. The 2 apiaries were set up in 1986 to provide overwintered colonies for the spring of 1987.

Data Collection — Apiaries I, II, and III — (1986-1987)

Data were collected from individual colonies at random. Data collected from colonies with queen loss or supersedure (after initial replacement period) were deleted from the analyses. All hive stands in the apiaries were occupied for the duration of the study.

Queen acceptance was recorded in the 2PK treatment colonies and in the V2Q and H2Q treatment divisions. Queen survival was monitored by locating queens in all colonies during the pre-flow brood count and at the end of the experiment. The 2 queens in the V2Q treatment were distinguished by their color marks.

In mid May, the area of brood was measured in the package colonies (2PK) and in the overwintered colonies that were being divided to assemble the V2Q and H2Q treatments. At the end of June, the pre-flow area of brood in all colonies was measured.

At the end of May, the colonies were weighed with a spring scale. After the main nectar flow, each colony was weighed again. Main flow net productivity was determined by subtracting the pre-flow weight from the post-flow weight and adjusting the value to allow for the weight of added honey supers.

In 1987, a warm spring provided an unusually good nectar flow at about the time overwintered colonies were divided. Early season productivity for this nectar flow was calculated from adjusted differences between pre- and post-flow weights.

Foraging activity was measured (16 July, 1986, 25 June, 1987, 29 June, 1987) by the technique used by Sugden and Furgala (1982b). Entrances of each colony were blocked for 45 sec. Photographs of colony entrances were taken with a 35 mm lens) in early afternoon (12:30-15:00 CST) on sunny days. The processed slides were projected and the number of returning foragers counted. The counts were then converted to number of foragers returning per minute.

Data were collected from each individual queen subunit, but reported on a paired 2-queen unit basis: (2PK, 2 packages; V2Q, parent and division; H2Q parent and division). Means for brood area, net productivity, and returning foragers were calculated for each treatment. In the analyses of individual apiaries (ANOVA), balanced data sets were maintained by calculating missing values. However, the combined data from the 3 apiaries were analyzed (ANOVA) using unbalanced data sets. Treatment means were separated by the Student-Newman-Keuls' procedure. Chi-square analyses determined whether queen acceptance and queen survival differed among treatments. Correlation analyses determined relationships between brood area, productivity, and foraging activity.

RESULTS AND DISCUSSION

At least 88% of the queens introduced into package colonies (2PK) and divisions (V2Q and H2Q) were accepted, which approached the expected 90-95% range. No significant difference ($P > 0.05$) among treatments were found (Table 1). Good acceptance of queens can usually be attained if disease-free queens from reliable commercial queen suppliers are used, sugar syrup is fed during introduction, and a period of flyback to parent colonies is allowed. Further, both V2Q and H2Q treatment divisions were left with populations of young bees which readily accept new queens.

No significant differences in queen survival ($P > 0.05$) were found prior to the main nectar flow (Table 1). Over 95 percent of the newly introduced queens were present in late June after the spring buildup period. However, by early fall significant differences occurred among the treatments ($P < 0.01$). Nearly 90 percent of the young queens were found in the H2Q and 2PK treatment units. But in the V2Q treatment units only 64% of the young queens remained. In the V2Q treatment, active dequeening is not practiced and removal of the queen excluder leaves the requeening to the bees. In this study, 27% of the V2Q treatment units superseded both the old and the young clipped and marked queens. The old queen survived in 9% of the V2Q treatment units.

These data on survival of queens corroborate results reported by Haydak and Dietz (1967). The loss of almost 4 of 10 newly purchased and accepted queens in V2Q treatment colonies is disturbing. Moeller (1976) found the vertical 2-queen system useful for requeening, but we found significantly better survival of young introduced queens in the H2Q and 2PK treatment units.

In all 3 apiaries, when the divisions were made in mid May, significantly less area of brood was found in the 2 package colonies (2PK) than in the overwintered colonies (V2Q and H2Q) ($P<0.05$) (Table 2). Although the package colonies had been established for about a month, brood production of 2 laying queens (2PK) did not match the brood production of the single queens in overwintered colonies (V2Q and H2Q) during this early spring buildup period.

By June, the combined data from the 3 apiaries showed no significant differences ($P>0.05$) in the pre-flow area of brood (Table 2). However, V2Q treatment units had significantly less brood ($P<0.05$) than did H2Q treatment units in one location (Apiary III). These results indicate brood production of package colonies (2PK) can equal that of V2Q and H2Q treatment parent-division combinations prior to the main nectar flow.

All 3 management system treatments precluded the tendency to swarm, a factor that enabled the colonies to become populous and productive before the onset of the main nectar flow.

Early season productivity of H2Q treatment units was significantly higher than that of V2Q treatment units ($P<0.05$) in Apiaries II and III in 1987 (Table 3). This result was somewhat surprising. One possible explanation may have been that the sudden loss of brood accompanying the H2Q division enabled the parent to reduce consumption of colony stores and divert bees to foraging. Another explanation may be that congestion occurred above the excluder in the taller V2Q colonies. The 2PK treatment units had significantly less gain ($P<0.05$) than both overwintered treatment units (V2Q and H2Q), which was probably due to the small early season foraging population in package colonies. Early season productivity was significantly correlated with the area of brood at the time divisions were made ($r = 0.605$, $P<0.01$, 63 df).

Table 1. Acceptance of queens and survival of queens in colonies managed as 2-queen unit systems in 3 apiaries, St. Paul, MN, 1986-1987.

Treatment	% [1] Acceptance of new queens	% [1,2] Surviving queens in early June	% [1] Surviving queens in late June	% [1] Surviving queens in late Oct.
2 Package colonies (2PK)	89 (66)	100	95 (66)	89 (66)
Vertical 2-queen (V2Q)	91 (33)	100	94 (33)	64 (33)
Horizontal 2-queen (H2Q)	88 (33)	100	97 (33)	88 (33)
Chi-square	0.16 (2 df) (P>0.9)		0.80 (2 df) (P>0.5)	15.79 (2 df) (P>0.01)

[1](n) in parentheses

[2]After initial replacement period.

Table 2. Mean area of brood in colonies managed as 2-queen unit systems, St. Paul, MN, 1986-1987.

Apiary[1]	Treatment	Brood area[2] mid May [sq. in.]	Brood area[2] late June [sq. in.]
1986			
I	2PK	1223 (30) b	3087 (210) a
I	V2Q	1509 (83) a	3361 (109) a
I	H2Q	1520 (74) a	3081 (154) a
1987			
II	2PK	1197 (40) b	3057 (89) a
II	V2Q	1932 (53) a	2895 (85) a
II	H2Q	1837 (43) a	2826 (90) a
III	2PK	1073 (45) b	3130 (74) ab
III	V2Q	1559 (64) a	2968 (122) b
III	H2Q	1668 (39) a	3317 (78) a
Combined	2PK (n = 30)	1163 (25) b	3102 (74) a
	V2Q (n = 30)	1694 (48) a	3044 (75) a
	H2Q (n = 29)	1684 (41) a	3097 (76) a

[1]Apiary I, n = 9; Apiaries II & III, n = 12.

[2]Mean ± (SE); Means within columns for each apiary followed by the same letter are not significantly different ($P>0.05$; Student-Newman-Keuls' test).

Table 3. Mean net productivity of colonies managed as 2-queen unit systems, St. Paul, MN, 1986-1987.

Apiary[1]	Trmt	Net weight[2] gain early flow [lbs.]	Net weight[2] gain main flow [lbs.]	Net weight[2] gain season [lbs.]
1986				
I	2PK	—	219 (8) a	
I	V2Q		211 (13) a	
I	H2Q		202 (13) a	
1987				
II	2PK	18 (3) c	317 (15) a	335 (15) b
II	V2Q	46 (6) b	272 (15) b	318 (19) b
II	H2Q	65 (4) a	327 (11) a	392 (13) a
III	2PK	16 (2) c	322 (11) b	337 (12) b
III	V2Q	31 (4) b	274 (14) c	305 (16) b
III	H2Q	48 (5) a	372 (16) a	420 (18) a
Combined				
	2PK (n = 30)		292 (11) b	
	V2Q (n = 30)		255 (10) c	
	H2Q (n = 29)		312 (16) a	

[1]Apiary I, n = 9; Apiaries II & III, n = 12.

[2]Mean ± (SE); Means for each apiary followed by same letter are not significantly different ($P>0.05$; Student-Newman-Keuls' test).

In 1986, main flow net productivity did not differ significantly among treatments ($P>0.05$) (Table 3). The net weight gain per 2-queen unit exceeded 200 lbs in all 3 treatments and was analogous to the long-term average honey surplus for east central Minnesota.

In 1987, the main flow net productivity was much greater due to extended and intense nectar flows. In Apiary II, the 2PK, and H2Q treatment units gained significantly more weight than the V2Q treatment units ($P<0.05$). The separation of means in Apiary III was complete ($P<0.05$), H2Q treatment units gained the most weight, and V2Q units gained the least weight. Main flow productivity was significantly correlated with the pre-flow area of brood in June 1987 ($r = 0.477$, ($P<0.01$, 63 df).

The combined main flow net productivity in Apiaries I, II, and III differed significantly ($P<0.05$) among the 3 treatments (Table 3). The greatest weight gains were attained by H2Q treatment units, the least net weight gains by the V2Q treatment units. The analysis of all 3 locations revealed a significant interaction ($P<0.05$) between treatment and apiary location. Although all treatments were more productive in 1987, the H2Q treatment units performed best under good nectar flow conditions.

In 1987, net productivity for the total season differed significantly ($P<0.05$) among treatments (Table 3). In Apiaries II and III, H2Q treatment units gained more weight than did the 2PK and V2Q treatment units.

No significant differences among treatments were found in the number of foragers returning per minute ($P>0.05$) (Table 4). The number of foragers returning was significantly correlated with main flow productivity ($r = 0.299$, $P<0.01$. 87 df) and pre-flow brood area ($r = 0.384$, $P<0.01$, 87 df) in the 3 apiaries.

By the onset of the main nectar flow, all 3 management system treatments produced populous colonies with brood areas and foraging activity that did not differ significantly. All of the management system treatments precluded swarming, provided adequate space for brood rearing and nectar storage, and prevented overt signs of diseases.

Historically, the 3 management systems compared in this experiment have been viable and practical systems. This comparison of management systems on a 2-queen basis seems more applicable than the previous 2-queen versus single-queen comparisons. Developments, such as standardized commercial equipment, chemotherapeutic agents, and a hybrid honey bee stock, enabled us to reduce some of the variation that occurs in honey bee field studies.

Currently, obtaining mite-free packages and queens is important to all 3 management systems. On the basis of productivity and queen survival, the horizontal 2-queen management system appears to be the best for a perennial non-migratory operation in the north central United States.

Table 4. Mean number of foragers returning per minute to colonies managed as 2-queen unit systems, St. Paul, MN, 1986-1987.

Apiary[1]	Treatment	Number of foragers[2] returning/min.
1986		
I	2PK	241 (17) a
I	V2Q	275 (25) a
I	H2Q	233 (21) a
1987		
II	2PK	268 (17) a
II	V2Q	274 (17) a
II	H2Q	235 (17) a
III	2PK	273 (19) a
III	V2Q	255 (19) a
III	H2Q	269 (32) a
Combined	2PK (n = 30)	261 (11) a
	V2Q (n = 30)	270 (12) a
	H2Q (n = 29)	251 (16) a

[1]Apiary I, n = 9; Apiaries II & III, n = 12.

[2]Mean ± (SE); Means for each apiary followed by same letter are not significantly different ($P>0.05$; Student-Newman-Keuls' test).

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