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# Adaptability Evaluation and Annual Production Model of Chinese Vegetable Varieties in Burundi

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**Abstract** Burundi is one of the least developed countries identified by the United Nations. Vegetable is the main crop in Burundi, but the variety is relatively simple and the planting level is low. Making use of the rich vegetable varieties and advanced cultivation techniques in China, the adaptability evaluation of new vegetable varieties in China was jointly carried out in Burundi to screen the vegetable varieties suitable for local cultivation. The purpose of this paper is to study the integration of high-yield cultivation techniques and annual production model to improve the level of vegetable cultivation in Burundi. From 2009 to 2015, our unit, together with the Burundian Fruit and Vegetable Promotion Center, carried out screening experiments on 144 vegetable varieties, such as tomato, balsam pear, chieh-qua, wax gourd, and cabbage. Through the methods of preliminary screening and experimental screening, the vegetable varieties suitable for planting in Burundi were selected, and the cultivation techniques of some main vegetable varieties were studied. The demonstration new varieties and new techniques were integrated to verify the high-yield cultivation techniques in the field. In 2009, 18 varieties suitable for local planting were selected from 96 vegetable varieties. In 2010, 40 vegetable varieties were selected for screening test, and 9 varieties suitable for planting in Burundi were selected. In 2011, 27 vegetable varieties selected in 2009 and 2010 were further evaluated for adaptability, and 13 vegetable varieties with high yield, strong resistance and good marketability were selected. Among them, there were 5 melon vegetables, 3 solanaceous fruit vegetables, 1 legume vegetables and 4 leafy vegetables. The cultivation techniques of some vegetable varieties were studied from 2011 to 2012, and the key points of cultivation techniques of chieh-qua and other vegetable varieties were clarified. According to the ecological characteristics of two main vegetable producing areas (the plateau and plain areas of Burundi), six sets of annual production and cropping arrangement plans covering melons, leafy vegetables, solanaceous fruits, beans and other vegetables were put forward, and the annual production model of multiple cropping and three-dimensional cultivation was integrated. From 2014 to 2015, according to the previous test results and market demand, 8 vegetable varieties were selected for Burundi to carry out screening experiments. 4 varieties with good yield and adaptability were selected for two consecutive years in 2014 and 2015. The integrated demonstration and effect verification of some selected vegetable varieties and cultivation techniques were carried out from 2015 to 2016, and the comprehensive advantages such as field yield and economic benefit were obvious. In this study, the adaptability of Chinese vegetable varieties in Burundi was evaluated, and 17 vegetable varieties suitable for local production were selected, including 5 melon vegetables, 5 solanaceous fruit vegetables, 1 legume vegetables and 6 leafy vegetables. This paper studies the integrated cultivation techniques and annual production model with obvious advantages in yield and benefit, which plays an important role in improving the planting level and benefit of vegetables in Burundi.

**Key words** Burundi, Vegetables, Evaluation, Screening, Verification

## 1 Introduction

Agriculture is a key area of China-Africa cooperation. With the establishment of the China-Africa Cooperation Forum, especially the proposal of the "Belt and Road Initiative", China-Africa agricultural cooperation has been continuously deepened and expanded, and the cooperation mechanism has become increasingly perfect. Located on the southern side of the equator in east-central Africa, the Republic of Burundi is one of the 10 poorest countries in the world as declared by the United Nations. Hunger and poverty are two major problems that have long plagued the government

and people of Burundi. Technical assistance is the focus of China's assistance to Africa, but it has not yet become a standardized system. Vegetable has short production cycle, high yield and high nutritional value, which is an important field of agricultural science and technology cooperation between China and Africa. This is of great significance to solving the problem of food and clothing for the Burundian people and improving local living standards. Chinese experts have carried out trials on new vegetable varieties including eggplant, towel gourd, balsam pear, wax gourd, cucumber, cowpea and so on in the Federated States of Federated States of Micronesia in Oceania<sup>[2]</sup>. They have carried out trial planting of cabbage, broccoli, cucumber, black wax gourd and cowpea in the African country Algeria and achieved success, and the product quality is good<sup>[3]</sup>. Their vegetable varieties such as melons, solanaceous fruits, leafy vegetables and legumes in Tanzania have good adaptability and have obvious potential to increase production in both rainy and dry seasons<sup>[4]</sup>. In Burundi, Africa, Chinese ex-

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perts summarized the current situation of agricultural development in Burundi, and introduced the natural conditions, limiting factors and measures of agricultural development in Burundi<sup>[5]</sup>. They have studied the breeding system and extension model of improved crop varieties in Burundi<sup>[6]</sup>, in order to provide reference for deepening agricultural cooperation between China and Burundi. They have discussed the formation conditions, basic types, properties and improvement and utilization of soil in Burundi<sup>[7]</sup>, providing a reference for decision-makers and the rational development and utilization of soil resources in Burundi. The trial planting, diseases and pests for rice<sup>[8]</sup>, corn<sup>[9]</sup> and other crops in Burundi were studied or reported. Burundi is an agricultural and animal husbandry country, the economy is mainly based on agriculture, agricultural population accounts for 90%, the level of agricultural production is relatively low, and crop production is low. Vegetables are the main crops in Burundi, but due to irrigation conditions, varieties, technology, consumption habits and other reasons, the varieties of vegetables are relatively single, the selectivity is less, and the production level is backward, which has seriously affected the balanced nutritional intake of the local people. There are high similarities in climatic conditions, natural conditions and agricultural production between Burundi and Guangxi, China. The vegetable varieties and cultivation techniques provided can be directly applied to local production after slight improvement. The demonstration and popularization of key techniques for increasing vegetable production can greatly improve the level of vegetable production in Burundi, which is of great significance to improving vegetable safety and improving people's livelihood in African countries. In this study, we jointly carried out a study on the adaptability of Chinese vegetable varieties in Burundi, explored the vegetable varieties suitable for the climate characteristics of Burundi, and studied the matching techniques for high yield and high efficiency, so as to form a suitable local vegetable high-yield cultivation technology and annual production model, and promote the improvement of vegetable cultivation level and sustainable development in Burundi.

## 2 Materials and methods

**2.1 Test materials** From 2009 to 2011, our unit provided 136 varieties of melons, solanaceous fruits, legumes and leafy vegetables to the Fruit and Vegetable Promotion Center, Ministry of Environment, Agriculture and Livestock (FVPC) (Table 1: 1–136), and 8 varieties of solanaceous fruits and leafy vegetables from 2014 to 2015 (Table 1: 137–144).

### 2.2 Test methods and measurement indexes

**2.2.1 Variety evaluation and screening test.** The experiment was carried out at the FVPC experimental base, which is located on the outskirts of Bujumbura at 756 m above sea level. The average annual temperature is 20–25 °C, the highest is 33 °C, and the average annual rainfall is 1 000–1 140 mm. The base is an important base for the promotion and demonstration of fruits and vegetables in Burundi, and the soil is alluvial soil. The soil quality is

sandy loam, the soil pH value is 6.13, and the content of soil organic matter and available phosphorus is low. 136 Chinese vegetable varieties were screened from 2009 to 2010. In 2011, 27 varieties selected in the previous two years were selected for further adaptability screening test. The relevant planting area of 27 varieties is shown in Table 2. According to the previous test results and market demand, the screening tests of 8 new varieties provided according to the previous test results were carried out for 2 consecutive years from 2014 to 2015. The planting area of the relevant varieties is shown in Table 3. 333.33 m<sup>2</sup> of each variety was planted, there was no repetition, and the yield was averaged. The spacing in the rows and spacing between rows for each vegetable variety was set according to the routine, and the commercial fruit (edible part) was picked and weighed during the harvest period. The Chinese cabbage, kale, flowering cabbage, chieh-qua and other crops harvested at one time were measured by the method of yield measurement and actual harvest in the plot. For tomato, pepper, eggplant, balsam pear, kidney beans and other continuously harvested crops, the method of harvesting all the mature products at one time in the plot and estimating the total output according to the harvesting records was adopted. Plant diseases and pests and resistance performance were recorded in detail in the process of planting. The level was evaluated comprehensively by yield and resistance performance. The specific requirements for each level are as follows: comprehensive evaluation level 5: good growth, high yield, few diseases and pests, strong resistance and good quality; comprehensive evaluation level 4: good growth, high yield, occasional diseases and pests, strong resistance and good quality; comprehensive evaluation level 3: common growth, average yield, occasional diseases and pests, medium resistance, average quality; comprehensive evaluation level 2: poor growth, low yield, diseases and pests, poor resistance, poor quality; comprehensive evaluation level 1: high mortality, low yield, common diseases and pests, poor resistance.

**2.2.2 Experiment on high-yield cultivation techniques of chieh-qua.** From 2011 to 2012, in order to further obtain high-yield cultivation technical parameters of chieh-qua and other vegetables, according to the climatic and geographical characteristics of Burundi, the experiment of high-yield cultivation model of chieh-qua was carried out in FVPC experimental base. Four treatments were set up in the experiment: (i) shelving + straw covering; (ii) creeping; (iii) creeping + straw covering; (iv) creeping (CK). Each treatment was repeated 3 times, and the planting area of each replicate was 222.2 m<sup>2</sup>. The method of direct seeding after budding was used for single-row planting. 666 plants were planted with a distance of 50 cm (666.7 m<sup>2</sup>), double vines for one single melon. The soil fertility was consistent and managed normally under natural conditions. In the process of management, the number of diseased plants was recorded and the incidence was calculated. According to the picking standard of ripe chieh-qua, the weight of picked fruit was recorded.

**Table 1** List of vegetable varieties jointly evaluated by China and Burundi

Number	Species	Variety	Number	Species	Variety	Number	Species	Variety	Number	Species	Variety
1	Balsam pear	Guinongke 1	37	Pumpkin	Miben pumpkin	73	Tomato	Nobel	109	Leaf mustard	Kangrezhujie
2		Guinongke 2	38		Hongshuangxi	74		Hongfentianshi	110		Guijie 1
3		Guinongke 3	39		Huli 1	75		Shengfen	111		Fengweichunjiecai
4		Darou 2	40		Cuili 1	76		Beiya 6	112		Yanxuan
5		Darou 1	41		Hongsheng 12	77		Hongman 1	113		Jinsijie
6		Cuizhu	42		Lihongmiben	78		Huangguan 333	114	Romaine lettuce	Huangdi
7		Fenglu	43	Zucchini	Cuifeng	79		Huangguan 666	115		Kaisa
8		Jinchuan	44		Guiyan 1	80		Jingguan 1	116		Dongfangfuxing
9		Yuchuan	45		HCO9	81		Xinxing 101	117		Yidalishengcai
10	Chieh-qua	Guiyou 1	46		Cuiying 101	82	Snow pea	Raopingdahua	118		Bolishengcai
11		Guiyou 2	47		Zhenyu 6	83		Dajiawandou	119		Ziyeshengcai
12		Guiyou 5	48		Jinghu 2	84		Dajiahelandou	120		Meiguodasusheng
13		Guiyou 6	49	Eggplant	Shijiezichangqie	85	Kidney bean	Baofengyoudoujiao	121	Broccoli	Shanghai 1
14		Guanxing 2	50		Xiongba	86		Fengcheng 2	122		Yunnan Xiyeqinghua
15		Yuenong	51		Nongfuchangqie	87		Fengcheng 3	123		Dayeqinghua
16		Yueke 6	52		Ruifeng 1	88		Liangqingdoujiao	124		Youxiu
17	Wax gourd	Guishu 1	53		Ruifeng 2	89		Feiyudoujiao	125		Luling
18		Guishu 2	54		Ruifeng 3	90	Chinese cabbage	Zaoshu 5	126	Lettuce	Jianyezisun
19		Yueguan wax gourd	55	Chili pepper	Guijiao 5	91		Xiayangbaicai	127		Liuyesun
20		Tiezhu 168	56		Guijiao 7	92		Qinbai 7	128	Flowering cabbage	Youlu 501
21		Heixianfeng	57		Guijiao 8	93		Liangqingbaicai	129		Bilucutaicaixin
22		Juren 2	58		Jintian 1	94		Qingjiangbaicai	130		Cuilubashitian
23		Guangdong Heipi	59		Jintian 3	95		Qingmaye	131	Cauliflower	Zhenqing 3
24	Cucumber	Shenqing 971	60		Yuejiao 1	96	Little cabbage	Shanghaiqing	132		Xinhuabashitian
25		Youxiu	61		Yuejiao 3	97		Chunyou 1	133		Lingxiu
26		Yinxiangeuiyu	62	White radish	Hongxin 90	98		Jingguan 1	134		Taisongyibaitian
27		Cuili	63		Nanpanzhou	99		Yangzhouqing 1	135		Tianjiaohuayecai
28		Ruili 268	64		Xuedan 1	100		Xiakang	136		Taisongliushiwutian
29		Jinchun 4	65		Eluobo 3	101	Kale	Xialian	137	Eggplant	Ruifeng 5
30	Towel gourd	Huangguan 3	66		Xiabao	102		Zhonggan 21	138	Tomato	Guihong 1
31		Huangguan 1	67		Baisha 13	103		Jin 8398	139		Zirufanqie
32		Cuixiu	68	Carrot	Honghu	104		Jingfeng 1	140	Kale	Zaobai 1
33		Siguawang	69		Chiyuwucun	105	Spinach	Huochetou 2	141		Qiugan 3
34		Xiatang 1	70		Jinghongwucun	106		Jingbo 8	142	Amaranth	Yuanyehongmixian
35		Chunyou	71	Indian lettuce	258	107		Dingxia spinach	143		Qingmixian
36	Okra	Thailand okra	72	Gutweed	Xiatian	108	Amaranth	Baimixian	144	Towel gourd	Yalu

**2.2.3** Integration of high-yield cultivation techniques and field verification. From 2015 to 2016, taking the vegetable varieties planted by local farmers in Burundi as the control, and using the same local planting method, the multi-point field effects of major vegetable varieties such as Nobel tomato, Ruifeng 1 Chinese eggplant and Zhonggan 21 cabbage were verified for 2 consecutive years. The main yield indexes and economic benefits of large area planting in the field were obtained. According to the actual situation in Burundi, the concentrated contiguous planting area was over 3 000 m<sup>2</sup>, and there was no replication. And cabbage was fully harvested at one time in the mature period, and

eggplant and tomato were harvested at one time to achieve commercial maturity. According to the method of estimating the total yield according to the harvest records, the output takes the average value of 2 years. The yield-increasing effect, cost calculation and economic benefit per unit area under the mode of multiple cropping and three-dimensional planting of vegetables are provided by FVPC.

**2.3 Data processing** MS-Excel 2019 was used for data processing. Variance analysis and multiple comparison were performed by One-Way ANOVA and Duncan ( $\alpha = 0.01, 0.05$ ) in SPSS 16.0 statistical software.

### 3 Results and analysis

**3.1 Evaluation of variety adaptability** In 2009, our unit provided 96 vegetable varieties such as balsam pear, chieh-qua and wax gourd to FVPC, and 18 varieties suitable for Burundian climate, consumption demand and production conditions were selected. In 2010, on the basis of 2009, 40 vegetable varieties were selected for adaptability test, and 9 varieties suitable for local planting were selected. In 2011, 27 vegetable varieties with good comprehensive performance (18 in 2009 and 9 in 2010) selected from 2009 to 2010 were further screened, and 13 varieties with good comprehensive characters such as high yield, strong resistance and good marketability were obtained. Among them, there were 5 melon vegetables (Guinongke 1 balsam pear, Guinongke 2 balsam pear, Guiyou 1 chieh-quaa, Guiyou 5 chieh-qua and Huangguan 1

towel gourd; there were 3 solanaceous fruit vegetables (Nobel tomato, Ruifeng 1 Chinese eggplant and Guijiao 7 pepper); there was 1 legume vegetable (Fengcheng 2 cowpea); there were 4 leafy vegetables (Zaoshu 5 Chinese cabbage, Zhonggan 21 kale, Italian lettuce and Youlu 501 flowering cabbage). Screening experiments on 8 new vegetable varieties were carried out for two consecutive years from 2014 to 2015. Four varieties with good comprehensive characters such as high yield, strong resistance and good marketability were obtained (Table 3): Ruifeng 5 Chinese eggplant, Guihong 1 tomato, Zaobai 1 kale and round leaf amaranth. The results of the evaluation of the adaptability of 27 vegetable varieties screened in 2011 in Burundi are shown in Table 2. The results of adaptability evaluation of 8 varieties from 2014 to 2015 are shown in Table 3.

**Table 2 Evaluation of adaptability of 27 Chinese vegetable varieties in Burundi (2011)**

Number	Species	Variety	Planting area//m <sup>2</sup>	Real yield//kg	Converted yield//t/ha	Diseases, pests and plant growth conditions	Evaluation level	Excellent or not
1	Balsam pear	Guinongke 1	333.33	1550	46.50	The plant grows vigorously, no blight and Fusarium wilt are found.	5	Yes
2		Guinongke 2	333.33	1 662	49.86		5	Yes
3		Cuizhu	333.33	1 305	39.15		3	No
4	Chieh-qua	Guiyou 1	666.67	4 510	67.65	The plant grows vigorously, no blight and Fusarium wilt are found, and the taste is good.	5	Yes
5		Guiyou 2	666.67	4 125	61.87		3	No
6		Guiyou 5	666.67	4 623	69.34		5	Yes
7		Guiyou 6	666.67	4 421	66.31		3	No
8	Eggplant	Shijiezichangqie	133.33	605	45.38	The plant grows vigorously, and cotton bollworm is occasionally seen.	3	No
9		Ruifeng 1	133.33	752	56.40		4	Yes
10	Tomato	Nobel	133.33	690	51.75	The plant grows vigorously, and cotton bollworm is occasionally seen.	4	Yes
11		Dongfang 1	133.33	778	58.35		3	No
12		Taiwanshengnuguo	133.33	480	36.00	The plant grows ordinarily, and cotton bollworm is seen.	3	No
13	Chili pepper	Guijiao 5	133.33	520	39.00		3	No
14		Guijiao 7	133.33	760	57.00	The plant grows vigorously, and cotton bollworm is occasionally seen.	4	Yes
15	Towel gourd	Huangguan 1	133.33	790	59.25	The plant grows vigorously, with a small amount of downy mildew.	4	Yes
16		Huangguan 3	133.33	720	54.00	The plant grows ordinarily, and downy mildew can be seen.	3	No
17	Chinese cabbage	MQ003	133.33	520	39.00	The plant grows vigorously, and cabbage worm and cabbage moth are occasionally seen.	3	No
18		Zaoshu 5	133.33	455	34.13		4	Yes
19		Xiayangbaicai	133.33	608	45.60	The plant grows vigorously, and there are cabbage worm, diamondback moth and snail.	3	No
20	Flowering cabbage	Youlu 501	133.33	621	46.58	The plant grows vigorously, and is harmed by cabbage worm and cabbage moth.	4	Yes
21	Kale	Jingeng 1	133.33	605	45.38	The plant grows vigorously, and is harmed by cabbage worm, cabbage moth.	3	No
22		Zhonggan 21	133.33	756	56.70		4	Yes
23	Cowpea	Fengcheng 2	133.33	756	56.70	The plant grows vigorously, and pod borer, rust disease are occasionally seen.	4	Yes
24	Kidney bean	CD109	133.33	652	48.90		3	No
25	Romaine lettuce	Italy Romaine lettuce	133.33	812	60.90	The plant grows vigorously, and is free from diseases and pests.	5	Yes
26	Crown daisy	TH009	133.33	510	38.25		3	No
27	Basella alba	GX50	133.33	330	24.75		3	No

**Table 3 Evaluation of adaptability of 8 Chinese vegetable varieties in Burundi (2014 – 2015)**

Number	Species	Variety	Planting area//m <sup>2</sup>	Average yield//t/ha	Diseases, pests and plant growth conditions	Evaluation level	Excellent or not
1	Eggplant	Ruifeng 5	333.33	62.50	The plant grows vigorously, moderately resistant to major diseases, and a small number of whiteflies appear.	5	Yes
2	Tomato	Guihong 1	333.33	59.86	The plant grows vigorously, and cotton bollworm is occasionally seen.	5	Yes
3		Ziruifanqie	333.33	49.15	The plant grows ordinarily, and is susceptible to virus disease.	3	No
4	Kale	Zaobai 1	333.33	47.31	The plant grows vigorously, and is harmed by cabbage worm, cabbage moth.	5	Yes
5		Qiugan 3	333.33	37.87		3	No
6	Amaranth	Yuanyehongmixian	333.33	46.34	The plant grows vigorously, and has strong disease resistance.	5	Yes
7		Qingmixian	333.33	40.31	The plant grows vigorously, and has strong disease resistance.	4	Yes
8	Towel gourd	Yalu	333.33	42.38	The plant grows ordinarily.	3	No

The main biological characteristics of 17 adaptable varieties selected in 2009 – 2015 (13 in 2009 – 2011 and 4 in 2014 – 2015) in Burundi are as follows: (i) Guinongke 1 balsam pear. The main and lateral vines can bear melons, and there are mostly female flowers. Continuous melon bearing ability is strong, and it is precocious. The first female flower has 8 – 12 nodes, and the commercial melon peel is oil-green. The average weight of single melon is 390 g and its cold tolerance is good. (ii) Guinongke 2 balsam pear. Precocious, the first female flower has 10 – 15 nodes. Commercial melon peel is emerald green, and melon is rod-shaped. The base of a flower is round, and the flesh is 1.4 cm thick. The average weight of single melon is 450 g, and it has good cold tolerance. When the temperature is 12 – 23 °C, it can blossom and bear fruit normally and the fruit can develop and expand normally. Medium resistance to powdery mildew and *Fusarium* wilt. (iii) Guiyou 1 chieh-qua. The melon is short and cylindrical in shape, with a length of 30 to 32 cm, a transverse diameter of 9 cm, and a thick flesh with a small cavity. Tender melon has white spots in turquoise, and the weight of single melon is about 1 kg. The old ripe melon is covered with white wax powder, and the single melon weighs about 2 kg. (iv) Guiyou 5 chieh-qua. The melon is 25 – 28 cm long, with plum blossom spots on the peel and no wax powder. The flesh is tender green, and the single melon weighs 1.25 kg, and is resistant to powdery mildew and downy mildew. (v) Huangguan 1 towel gourd. Commercial melon has long stick shape, melon skin color is green, and it is relatively uniform. Middle-maturing varieties, the harvest time after spring sowing is 50 – 60 d, and the harvest time after autumn sowing is about 45 d. The melon body is soft, the fiber is few, the melon flesh is white, and the flesh is sweet. Heat-resistant, more resistant to angular spot and downy mildew. (vi) Nobel tomato. Precocious, vigorous growth, no premature senility. The fruit is red and glossy, flat and round. The weight of single fruit is 150 to 200 g, the taste is good and the texture is hard. It can be stored for 30 d after harvest, resistant to transportation and storage. Resistant to bacterial wilt and late blight. (vii) Ruifeng 1 Chinese eggplant. Mid-early ripening, the fruit is long stick-shaped, the lower end of the fruit is obtuse. The commercial fruit has a length of 30 cm, a diameter of 4.5 cm and the average weight of single fruit is 250 g. The skin of ripe fruit is purple, black and shiny. The skin is white, the flesh is tender, the quality is good, and the stress resistance is strong. (viii) Guijiao 7 pepper. The growth of

the plant is strong, and the fruit setting rate is strong and the fruit is dark green. The red fruit is smooth and bright, spicy and fragrant, and can be eaten or processed. Strong heat resistance, resistance to virus disease, anthracnose, blight and bacterial wilt. (ix) Fengcheng 2 cowpea. Early maturity, high yield, heat resistance and disease resistance. The pod is about 65 cm long, the color is green and glossy, the flesh is refreshing and sweet, and the flesh is thick and durable for storage. The plant grows vigorously, has many branches and strong reproduction ability, and the yield is about 30 t/ha. (x) Zaoshu Chinese cabbage 5. Precocious, heat-resistant, moisture-resistant, high resistance to virus disease, downy mildew, soft rot, anthrax. It is suitable for the cultivation of little cabbage in the period of high temperature and heavy rain. It can be harvested 25 d after sowing, and it is also cultivated as celery cabbage in early autumn. The growth period is 50 – 55 d, the weight of leaf head is about 1.5 kg, and the yield is 60.0 – 75.0 t/ha. (xi) Zhonggan 21 kale. The leaves are crisp and tender, spherical, beautiful in appearance, not easy to crack, and of good quality. The weight of single fruit is about 1 kg, and the yield can reach about 50 t/ha after 50 d of harvest. (xii) Italian lettuce. The leaf clusters grow straight, the leaves are scattered, and the plant height is about 25 cm. Crisp and tender quality, no fiber, raw or cooked food. It is harvested 40 d after planting, and the weight of single plant was 0.2 – 0.4 kg. It is suitable for planting in spring and autumn, greenhouse and open field. (xiii) Youlu 501 flowering cabbage. Precocious, 28 – 33 d from sowing to initial harvest. The plant is erect, short and strong, and the plant height is 24.7 cm. The leaf is oval, the bolt color is oily green and shiny, the bolt diameter is 1.5 cm, and the bolt weight is 25 g. Crisp, sweet, resistant to downy mildew, anthracnose and soft rot, moderate heat and waterlogging resistance. (xiv) Ruifeng 5 Chinese eggplant. Mid-early maturity, strong plant growth. It is about 80 – 100 d from sowing to initial harvest, the fruit is long tube-shaped, 30 – 35 cm long, with a transverse diameter of 4.5 – 5.0 cm, and the weight of single fruit is 280 g. The fruit skin is dark purple, the flesh is white, the pericarp is thin, the flesh is tender and the quality is good. Moderately resistant to blight and other major diseases, there are a small number of whiteflies and so on. It is suggested that about 20 000 plants/ha should be sown locally, and the yield is generally 60 – 70 t/ha. (xv) Guihong 1 tomato. Mid-early maturity, light green leaves, glossy red fruit, flat round. The single fruit is 160 – 180 g in

weight, hard in texture, resistant to transportation and storage. It can be stored for more than 30 d after harvest. Moderately resistant to tomato blight, late blight, gray mold and other major diseases, and a small number of cotton bollworms appear during the planting period. It is suggested that about 30 000 plants/ha should be sown locally, medium fertilization should be applied, and the yield is generally 50–60 t/ha. (xvi) Zaobai 1 kale. The leaves are crisp and tender, spherical and beautiful in appearance. The bulb is tight, not easy to crack, and the quality is good. There are few diseases and pests, and the single bulb weight is about 1.0–1.5 kg. The density is 30 000–35 000 plants/ha. It takes about 50 d from planting to harvest, and the yield is generally 40–50 t/ha. (xvii) Round leaf amaranth. The leaves are large and round, with crimson leaves and few fibers. It is fresh and tender and the color is bright. It takes about 20–30 d from sowing to picking, medium fertilization is conducted, and it prefers nitrogen fertilizer and farmyard manure. The yield is generally 40–50 t/ha.

### 3.2 Study on high-yield cultivation techniques of chieh-qua

In order to make full use of agricultural resources in Burundi, a study on straw covering and shelving cultivation was carried out. The effects of different cultivation patterns on the yield and disease occurrence of chieh-qua are shown in Table 4. The results showed that the yield in treatment 1 "shelving + straw covering" was the highest, reaching 0.88 t/ha, which was 152% higher than that of the control. The rate of diseased plants in shelving cultivation was significantly lower than that in creeping cultivation. Straw covering can significantly increase the yield of chieh-qua, especially in the dry season when water is insufficient. Creeping cultivation is a natural cultivation method in Burundi, which not only has a high incidence of disease, but also has a low yield. "Shelving + straw covering" should be the efficient cultivation and production mode

of chieh-qua under natural conditions in Burundi.

**Table 4** Effects of different treatments on yield and disease occurrence of chieh-qua

Treatments	Rate of diseased plant // %	Yield // t/ha
Shelving + straw covering	19.72 ± 0.69 dD	0.88 ± 0.03 aA
Shelving	29.34 ± 0.53 cC	0.66 ± 0.03 cB
Creeping cultivation + straw covering	36.65 ± 0.63 bB	0.75 ± 0.02 bB
Creeping cultivation (CK)	69.60 ± 0.32 aA	0.30 ± 0.01 dC

Note: The data in the table are analyzed by Duncan ANOVA, uppercase and lowercase letters indicate that there are significant differences between treatments at 0.01 and 0.05 levels, respectively.

### 3.3 Study on the integration of annual production and cropping arrangement patterns of vegetables

The climate of Burundi is unique, mainly divided into dry season (May–October) and rainy season (November–April), with distinct seasons and obvious regional climate characteristics. Due to the relatively few local water conservancy facilities and vegetable cultivation facilities, vegetable cultivation basically depends on natural precipitation. In order to realize the annual production and perennial supply of vegetables, and improve the output value and benefit of vegetable production, after 3 years of experiment and demonstration, the annual crop arrangement model of vegetable production in IMBO plain and plateau area was explored and summarized. It has formed six multiple cropping and three-dimensional cultivation patterns covering melons, leafy vegetables, solanaceous fruits, beans and other major local vegetables. The annual crop production and cropping arrangement patterns of vegetables in IMBO plain and plateau areas are shown in Tables 5 and 6 respectively.

**Table 5** Arrangement pattern of annual vegetable production and cropping in IMBO plain areas

Models	The first stage	The second stage	The third stage	The fourth stage
Model 1	April–June: heat-resistant cabbage (Kuaicai, Xiayangbai, Zaoshu 5)	June–August: fresh corn, edamame beans	September–December: melons (balsam pear, towel gourd, chieh-qua, wax gourd, pumpkin, zucchini)	October–March: intercropping between leafy vegetables (flowering cabbage, kale, Romaine lettuce, amaranth, crown daisy, lettuce) and melons
Model 2	May–August: edible beans (soybeans, taming beans, scarlet runner beans, red kidney beans)	September–March: interplanting between cold season leafy vegetables (flowering cabbage, cabbage mustard, Romaine lettuce, amaranth, crown daisy) and legumes	November–May: solanaceous vegetables (tomato, eggplant, chili pepper)	–
Model 3	March–October: interplanting between melons (balsam pear, towel gourd, chieh-qua, wax gourd, pumpkin, zucchini) and fresh corn and green soy beans	November–February: cold season leafy vegetables (kale, Chinese cabbage, cauliflower)	–	–

**Table 6** Arrangement pattern of annual vegetable production and cropping in plateau and mountainous areas

Models	The first stage	The second stage
Model 1	Interplanting between melons (balsam pear, towel gourd, chieh-qua, wax gourd, pumpkin, zucchini) and leafy vegetables (flowering cabbage, kale, Romaine lettuce, amaranth, crown daisy)	January–March: cold season vegetables (kale, Chinese cabbage, cauliflower)
Model 2	April–September: Interplanting between solanaceous vegetables (tomato, eggplant, chili pepper) and leaf vegetables (flowering cabbage, cabbage mustard, Romaine lettuce, amaranth, crown daisy)	October–March: tuber vegetables (carrot, white radish, turnip, potato, sweet potato)
Model 3	April–September: Intercropping between melons (balsam pear, towel gourd, chieh-qua, wax gourd, pumpkin, zucchini) and leafy vegetables (flowering cabbage, cabbage mustard, Romaine lettuce, amaranth, crown daisy)	October–March: Cold season vegetables (kale, Chinese cabbage, cauliflower)

### 3.4 Integration of high-yield cultivation techniques and field verification of varieties

The multiple cropping, three-dimensional planting and cultivation mode of vegetables is a comprehensive optimization model for the local traditional planting habits, and the land utilization rate is high. According to the data provided by FVPC, the average yield of extension and application area is 4.60 t/ha higher than that of local conventional planting pattern,

and the average cost saved is 3 500 yuan/ha. The main vegetable varieties popularized show higher yield advantages than the local main varieties by using the local planting method, with an average yield increase of more than 4.5 t/ha. At the same time, due to strong stress resistance, low demand for fertilizers and pesticides, relatively extensive management, there are obvious cost advantages (Table 7).

**Table 7 Field yield and comprehensive benefit of main vegetable varieties**

Variety	Demonstration site	CK	Comprehensive resistance	Yield//t/ha	Increase in production compared with CK//t/ha	Cost saved yuan/ha
Nobel tomato	Muzinda	Bel tomato	Moderate resistance	38.26	5.25	6 000
Ruifeng 1 eggplant	FVPC	Burundian eggplant	Resistance	41.38	4.50	42 000
Zhonggan 21 kale	IMBO	M1	Resistance	46.32	5.71	3 000
	FVPC	B1	Resistance	43.75	5.34	3 000

## 4 Discussion

Located near the equator and with a subtropical and tropical climate, Burundi is rich in temperature and light resources, which is very suitable for the development of agriculture. Affected by the level of social and economic development, there are few water conservancy projects in Burundi and the mode of production is relatively backward. There are few agricultural facilities such as net shed and simple seedling shed, and the degree of agricultural mechanization is very low, and it is mostly rain-fed agriculture. Vegetables are the main crop in Burundi and are indispensable in daily life, but they are relatively simple in type, less selective in

variety and simple in cooking and eating. According to the data published by FAO<sup>[10]</sup>, Burundi's fresh vegetable harvest area in 2018 was 59 000 ha, with a yield of 956 000 t and an average yield of 9 437 kg/ha. Vegetable production is shown in Table 8, mainly including potatoes, tomatoes, green peppers, eggplants, cucumbers, kale, pumpkins, carrots, taros, yams and other common types, as well as beans such as soybeans, peas, soybeans, and pigeon beans. Among them, the cultivation area of tomato and legume is larger, and small-scale continuous cultivation can be seen in the hilly area of about 1 000 – 1 500 m above sea level. French green beans and cassava leaves are also exported vegetables from Burundi.

**Table 8 Production of major vegetables in Burundi in 2018**

Species	Vegetables, fresh ness	Soybeans (dry)	Peas (dry)	Potatoes	Soybeans	Pigeon peas	Taro (cocoyam)	Yams
Area harvested//ha	58 949	599 139	2 572	27 097	4 582	2 060	7 349	809
Yield//kg/ha	9 437	656	1 913	11 169	521	1 147	7 620	8 559
Total production//t	9 556 281	393 233	4 919	302 665	2 387	2 363	56 006	6 925

In view of the natural climatic conditions and consumption habits of Burundi, the vegetables jointly evaluated by FVPC in Burundi are mainly heat-resistant vegetables, and local popular vegetables such as solanaceous fruits, leafy vegetables, edible beans and so on are chosen. After years of identification, 17 vegetable varieties which are suitable for local cultivation and are very popular in the market have been selected. Cabbage vegetables are one of the most important local vegetables, mainly used for cold vegetable dish in sauce. Experiments in different ecological regions showed that its quality was greatly affected by season and climate. The yield and quality in the plateau and mountain area from January to March were obviously better than those in other seasons, and also better than those in the plain area. Leafy vegetables are in great demand in the local area, and they are generally used for cooking raw food, soup or side dishes. The Italian lettuce screened by the experiment has the advantages of heat resistance, strong resistance, easy cultivation and high yield. The yield, quality and resistance of Italian lettuce in rainy season are obviously better than those in dry season. Legume vegetables are common in Burundi, generally cooked and eaten directly, and can

also be mixed with cassava powder and so on for cooking. The main varieties tested include kidney beans and cowpeas. The introduced Fengcheng 2 cowpea has good qualities such as early maturity, high yield, heat resistance and strong resistance, and its yield is higher in rainy season. Some varieties are suitable for planting in Burundi, but the market share is low. For example, the black-skinned wax gourd originating from China is easy to cultivate and manage; under the condition of low level of cultivation and management in Burundi, the yield is more than 5 000 kg. The quality is very excellent, which is similar to the situation of introduction and trial by Chinese experts in the Central African Republic<sup>[11-12]</sup>. Tomatoes, sweet peppers, melons and amaranth are the main varieties of vegetables eaten by Burundian residents, which are welcomed by the local people and have great market potential. The introduction, screening and integration of new varieties and new technologies are of great significance. The climatic conditions such as temperature and light resources in Burundi are very similar to those in Guangxi, and the risk of introduction and test of varieties in Guangxi and even South China is relatively low. According to the experimental results and local consumption habits, the in-



roduction, demonstration and promotion of the same series of varieties with good comprehensive characters and popular in the local area were carried out. For example, according to the superior local performance of the yield and quality of Ruifeng 1 Chinese eggplant, the research, demonstration and promotion of the same series of Chinese eggplant, such as sister variety Ruifeng 5, were carried out in depth. According to the characteristics of Nobel tomato variety (resistant to transportation, storage, bacterial wilt and late blight in Burundi), the introduction, demonstration and popularization of Guihong 1 and other tomato varieties with single fruit weight between 150 and 200 g, hard texture, transportation resistance and storage resistance have been increased. According to the characteristics of Zhonggan 1 kale variety (beautiful in appearance, not easy to crack, very popular in the market), Zaobai 1 kale variety, which is gradually withdrawn from the market in China but excellent in the comprehensive characters, has been demonstrated and planted. Good yield and market popularity can still be obtained. According to the performance of local varieties and market reaction, some varieties were adjusted appropriately, for example, the yield and quality of edible amaranth in the experiment were good, but they were not welcomed by the market, and the introduction, demonstration and promotion of new varieties such as green amaranth and round leaf amaranth were strengthened. getting twice the result with half the effort.

According to the needs of introduction and popularization, high-yield cultivation experiments were carried out. According to the climatic characteristics of IMBO plain, plateau and mountain area in Burundi, this paper explores and summarizes the annual production model of multiple cropping and three-dimensional cultivation of main vegetables, such as melons, leafy vegetables, solanaceous fruits, and beans. In the experiment of cultivation techniques, it is found that Burundian vegetables have a lot of room to increase production. We can improve the quality and yield of vegetables by simply changing or optimizing planting patterns, increasing the application of organic and compound fertilizers, and improving irrigation methods. In the experiment of efficient cultivation of chieh-qua, through the change of cultivation mode, the disease of chieh-qua was greatly reduced and the yield was increased by 152%. This shows that under the climatic conditions in Burundi, the appropriate optimization of cultivation pattern, the rational allocation of planting density, the scientific input of basic nutrients and the reasonable operation of water can greatly increase the vegetable yield. Burundi's climate characteristics, mode of production and consumption habits are very suitable for promoting the varieties and production patterns recommended by the project. The annual production technology can effectively alleviate the shortage of total vegetables in Burundi and will gradually produce greater social and economic benefits. The localization factor was paid attention to in the experimental design, and Burundian farmers could use local materials to carry out production effectively without increasing too much investment. In the prevention and control of diseases and pests, with the planting density and fertilizer input increase, the occurrence of diseases and pests will be

gradually aggravated. The research on disease resistance of introduced varieties should be strengthened and excellent varieties with disease resistance, barren tolerance and drought tolerance should be selected to promote the sustainable development of vegetables in Burundi.

## 5 Conclusion

In this study, the adaptability of 144 Chinese vegetable varieties in Burundi was evaluated, 17 vegetable varieties suitable for local cultivation were selected by considering yield, quality, resistance and other factors, and the matching high-yield cultivation methods were put forward. According to the ecological characteristics of the plateau and plain areas of Burundi, six sets of annual production and cropping arrangement plans covering melons, leafy vegetables, solanaceous fruits, beans and other vegetables were put forward, and the annual production model of multiple cropping and three-dimensional cultivation was integrated. This is of great significance to improving the level of vegetable production in Burundi.

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