Current Situations and Development Strategies for Integration of Peanut Agronomy and Agricultural Machinery in China

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Abstract The mechanization level of peanut production is the bottleneck restricting the development of peanut production in China, while integration of agronomy and agricultural machinery is an essential approach for improving mechanization level of peanut production. This paper elaborated requirements of peanut agronomy for agricultural machinery from peanut planting modes, land cultivation, sowing, harvesting, picking, and shelling, etc. Besides, it discussed requirements of agricultural machinery for agronomy from peanut seed quality, variety characteristics, planting modes, and soil condition. In addition, it analyzed existing problems and restricting factors of integration of peanut agronomy and agricultural machinery. Finally, it came up with recommendations for development strategies including increasing government fund input, optimizing industrial distribution, and multidisciplinary joint research.

Key words Peanut, Agronomy, Agricultural machinery, Simplified cultivation, Development strategies

1 Introduction

Peanut is an essential oil crop and cash crop of China, plays an important role in agricultural production, and stressing and developing peanut production is an effective approach for solving China's crisis of vegetable oil[1-3]. After entry to the 21st century, China's urbanization process is accelerating, and labor cost and price of means of production are rising constantly. In this situation, agricultural production should constantly simplify production process, reduce material input, reduce cost, and simplify cultivation[4]. China's agriculture remains the period transiting from traditional agriculture to modern agriculture. Agricultural machinery is an essential material foundation for modern agriculture and also important content and mark for realization of agricultural modernization[5]. In major process of peanut production, using mechanized operation can effectively reduce costs, up to 234 yuan/mu, and overall efficiency of mechanized cultivation is about 40 times the artificial cultivation[6].

In developed countries such as the United States, the whole production process, including sowing, pesticide spraying, intertillage and weeding, harvesting, and drying, has realized mechanization. Taiwan of China has also basically realized whole process mechanization in peanut production. In mainland China, the peanut production still remains at the early stage of development, the comprehensive mechanization level of production, cultivation and sowing is relatively low. In 2009, it was only 36.34%. The mechanized cultivation, sowing, and harvesting was 53.90%, 31.25%, and 18.02% respectively; especially the mechanized harvesting level, there was a big gap with rice (56.69%) and wheat (86.07%)[7].

At present, high labor cost, low planting benefit, and low mechanization level have become major bottleneck restricting peanut production development and industrial growth in China, and research and development of peanut production machinery have become a hot spot of China's agricultural mechanization development[8-10]. Accurate input, simplified management, standardized operation, and mechanized operation are overall development trend of China's peanut production and also primary tasks of peanut researches. China's modern agricultural production mainly consists of two basic contents: agronomy and agricultural machinery. Agronomy is the science and technology of producing and using plants for food, fuel, fiber, and land reclamation, while agricultural machinery refers to machines utilized for tillage, planting, cultivation, and harvesting of crops; modern agricultural production stresses common development of agronomy and agricultural machinery[11]. Therefore, organic integration of agronomy and agricultural machinery is inherent requirement and inevitable choice for building modern agriculture and also development direction for realization of agricultural modernization in China[12, 13]. In this study, we made elaboration of current situations and problems of integration of peanut agronomy and agricultural machinery, and came up with development strategies, in the hope of providing reference for promoting mechanized peanut production in China.

2 Requirements of peanut agronomy for agricultural machinery

Whole process mechanization of peanut production mainly refers to

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technologies for mechanical completion of whole process of peanut agronomy. It mainly consists of cultivation, sowing, management, harvesting, and processing, mainly including cultivation, soil preparation, sowing, film mulching, fertilizer application, field management, harvesting, picking, shelling, and post-production processing technologies. In the whole process, the core part is sowing and harvesting, which requires much labor and high labor strength[14].

2.1 Diverse planting modes needs flexible and diversified agricultural machinery As to peanut cropping system, peanut is mainly three crops in two years, two crops in one year, and one crop in one year. In southern area, there are also autumn sowing and winter sowing. In line with different cropping system, main production areas have established high yield cultivation modes for peanuts, such as spring sowing plastic film covering, interplanting with wheat, summer direct sowing in wheat stubble, intercropping with maize. Peanut intercropping with maize needs machinery suitable for sowing maize and peanut seeds; peanut interplanting with wheat needs mechanical equipment suitable for one or two men operation; peanut intercropping with fruit tree needs small field cultivation, sowing, management and harvesting machinery. For summer direct sowing in wheat stubble, residual stubble after wheat harvesting is higher than 20 cm, if using rotary tiller, the effect of straw returning to field is very poor, and generally it will exert great influence on peanut germination. Therefore, for summer direct sowing and ridging of peanut, the key is to crush and clean the wheat stubble.

2.2 Deep plowing needs high traction force of peanut plowing machinery High yield peanut needs deep, activated and loose soil construction and upper loose and bottom solid soil layer structure. The soil layer is deep, whole soil layer is above 50 cm, plowing layer is about 30 cm, and 10 cm peanut generation layer has loose soil and excellent penetration[15]. At present, most land parcels adopt rotary tiller, the plowing depth is 10 – 12 cm, which greatly restricts downward growth of peanut root system. Therefore, mechanical deep plowing or loosening is favorable for breaking plow pan and deepening the activated soil layer. Deep plowing is generally carried out before winter or early spring, but should not be later than the Tomb Sweeping Day, to promote soil maturation and preserve soil moisture[16]. Mechanical deep plowing should adopt deep plow and sub-soiler. When deep plowing exceeds 25 cm, the plow body should realize upper plowing and lower loosening, and excellent soil crushing performance. The subsoiler should realize upper tillage and lower loosening, topsoil tillage 15 – 20 cm, and deep loosening over 30 cm, to prevent loss of water due to evaporation, preserve soil moisture, and improve soil properties. In infertile arid land, it is required to promote big plow deep tillage. It is preferred to adopt large tractor driven deep plow with power higher than 100 horsepower, plowing depth more than 30 cm, to improve water conservation and fertility keeping ability of soil.

2.3 Fine sowing machine needs high sowing quality High yield peanut must have complete, unified, and robust seedlings. The germination rate should reached 99% and actual number of harvesting plants should be higher than 98%[15]. The level of crop population quantity is foundation of high yield of crop. Thus, high yield peanut needs high quality of peanut seeds. The sowing machine should be free of missing or repeated sowing, sowing should be uniform and sowing depth should be consistent at 3 – 5 cm depth. After sowing, promptly compact and spray herbicide, and the ridging quality should be high. In this situation, it is recommended to use high efficient fertilizer application technologies to research and develop accurate control of fertilizer application, and use combined peanut sowing machine and auxiliary accurate fertilizer application device, to solve problems of high fertilizer input, low fertilizer utilization rate, and high production cost.

2.4 Harvesting machine should accord with local situations, to realize common development of large, medium and small sized machinery Harvesting of peanut takes the longest time in the whole peanut production, about 1/3 of the whole peanut production process, and its operating cost accounts for more than 50% of peanut production costs; due to much labor, low efficiency, and high labor cost, peanut planting farmers bad need high efficient peanut harvesting machine[17, 18]. Mechanized harvesting includes mechanized segmented harvesting and combined harvesting, and the segmented harvesting machines include peanut digger, and combined peanut digger and harvester[19]. The combined peanut harvester can perform digging, soil separation, conveying, picking, cleaning, and gathering, so it is the full function peanut harvester[20].

In Huang-Huai-Hai region and southern areas, individual peanut production is widespread, and peanut production is mainly distributed in hilly and mountainous areas, the land parcels are small and decentralized. Therefore, peanut harvester should be light, convenient, sturdy and durable. In Xinjiang Uygur Autonomous Region, the terrain is flat and the land is large, so the peanut harvester should be suitable for large area operation.

2.5 Shelling and seed processing machinery Peanut production needs large quantity of seeds. At present, peanut seeds are sold and transported in the form of peanut pod. Conventionally, in 1 – 2 months before sowing, it needs shelling of peanut pod manually and screening and classifying the peanut seeds. Manual shelling features high quality of shelling and few damages of shelled peanuts. However, with shortage of labors and rising of labor cost, the manual shelling fails to satisfy demand of high efficient agricultural production due to low working efficiency and high cost[21]. Therefore, it is urgent to develop seed peanut mechanical shelling technology, reduce breaking rate of shelling, and improve mechanical peanut shelling level. In addition, peanut seeds are varied in size and mechanical sowing quality is low, so it is of great significance for screening and classifying peanut seeds before sowing.

3 Requirements of agricultural machinery for peanut agronomy

3.1 Seed quality Mechanical sowing is to achieve no repeated sowing, missing sowing, uniform sowing, and consistent sprouting, and it requires uniform peanut seed size and high seed vigor[22]. Therefore, before peanut sowing, it is required to classify seeds, reject oversize or undersize, mildew seeds and those seeds with color inconsistent with sowing requirements and special shape seeds, and adopt high effective poison-free insecticide and bactericide seed coating, and scientifically prevent and control underground pests, insects, and diseases. In the United States, depending on diseases, pests and insects, peanut seeds adopt corresponding insecticide and bactericide seed coating which is produced by seed companies. In China, peanut seeds are still packaged with shell, and manual shelling and screening are needed, resulting peanut seeds varied in size and not uniform in seed quality.

3.2 Peanut varieties and plant traits Mechanical harvesting of peanuts has many requirements for peanut variety characteristics; peanut plant, fruiting range, peg strength, and harvest time are traits determined by peanut varieties, and directly relate to effect of mechanical harvesting[10]. For erect type peanut varieties with small plant range, it is easy to realize plant dividing, regularly and orderly plant lifting and gripping through semi-feeding combined harvesting; for prostrate peanuts or semi-erect peanuts with large plant range, peanut plants can not be lifted completely, and it is difficult to realize accurate gripping, it is likely to have the problem of disorderly plants and twining of plants in the process of gripping and conveying, and consequently leading to blockage and tangling of peanut plants[23]. Peanut varieties suitable for picking machine should have plant height above 30 cm, pegs longer than 3 cm, neat pods, erect plants, and thin branches, and pods not vulnerable to break[24]; peanut varieties suitable for mechanical combined harvesting need centralized fruiting, long harvest time, tough pegs and not vulnerable to shedding, regular and uniform appearance of pods, high yield, high quality, and high stress resistance.

3.3 Planting modes Mechanical harvesting of peanuts should satisfy corresponding requirement of plant row spacing. Mechanical segmented harvesting requires that the row spacing should match working width of harvester and wheel tread of auxiliary power; for semi-feeding combined harvester, to raise the productivity, peanuts should adopt wide narrow row alternate planting. At present, the combined harvester for peanuts in China mainly adopts digging and pulling combined gripping conveying method. The existing gripping mechanism is suitable for row spacing lower than 300 mm, preferred below 280 mm; if larger than 280 mm, it may lead to missing gripping or missing harvesting, so peanut planting adopts wide narrow row alternating planting method. Small row spacing should be less than 280 mm, and big row spacing should be greater than 400 mm or 480 mm[25].

3.4 Soil conditions In wide peanut planting areas, soil types are various. Sandy soil is suitable for peanut growth, but loose soil is not suitable for wheeled harvester because of excessive sinking of tire. For clay soil, mechanical harvesting operation is ineffective and inefficient, and the performance is not stable.

No matter sandy soil, loam soil or clay soil, as long as the moisture content is suitable, mechanical harvester will operate smoothly, and the power consumption will be low, loss rate will be low, and fruit cleanness will be high. Mechanical harvester has the lowest requirement for moisture content of sandy soil, but has strict requirement for moisture content of loam soil and clay soil. When soil moisture content is in the range of 10 – 18% and the soil is loose in rubbing with hands, it is deemed as suitable for mechanical operation. If the soil moisture content is too high, mechanical harvesting will fail; if the soil moisture content is too low and soil is hardening, it is possible to properly irrigate to supplement moisture and adjust moisture content before mechanical harvesting.

4 Existing problems and restricting factors of integration of peanut agronomy and agricultural machinery

4.1 Planting modes are diversified and agricultural machinery is not adapted to agronomy requirements Except in Xinjiang, Huang-Huai-Hai plain, and the Yangtze River valley where peanuts are planted in large areas, individual planting of peanuts is widespread. In addition, most are located in hilly and mountainous areas, and land parcels are decentralized and rugged. As a result, it is difficult to realize mechanical operation and influence the application and extension of agricultural machinery. At present, types and models of traction vehicles for farming, sowing, or harvesting machines are relatively simple. For example, in Shandong Province, the main traction vehicle is small four-wheel tractor and walking tractor. For small four-wheel tractor, the wheel tread is about 90 cm; for walking tractor, the working width is 70 – 80 cm. In other words, the working width for both types of tractors is fixed. However, in main peanut production areas of China, planting modes are complex and diversified. There are flatten culture and ridge culture, also sole cropping, intercropping, and interplanting, and peanut planting row spacing is also diversified. Therefore, the existing peanut machinery does not match peanut planting modes, and the mechanical operation is quite difficult. Traditional agronomic measures including cultivation and breeding technologies are mainly pursuing high yield and high quality. Although there are diversified planting modes such as interplanting, intercropping, dense planting and thin planting, it neglects suitability of mechanical operation. As a result, the development of operating machinery is very difficult and it also increases difficulty of production mechanization to a certain degree. In the process of research and manufacture of agricultural machinery, it is still not standardized for researching and developing agricultural machinery combining different planting systems and different operating requirements. Agronomy fails to satisfy operating requirements of agricultural machinery, and agricultural machinery fails to adapt to

operating conditions of agronomy, both hinder the mechanization development[8].

4.2 Mechanical sowing peanuts have problems of uneven seedlings and low fertilizer utilization efficiency In recent years, with constant improvement in peanut sowing machine, it greatly reduces farmers' labor strength, raises operating efficiency, and majority of peanut sowing machines can complete agronomic requirements including ditching, sowing, fertilizer application, pesticide spraying, film covering, and soil covering just in one time. However, there is still a big gap with standardized peanut cultivation, mainly manifested in uneven seed sowing, not uniform depth, shallow and concentrated fertilizer application, and lack of quantitative control. As a result, it leads to uneven seedlings, low fertilizer utilization efficiency, rotten peanuts, and consequently influencing yield and quality of peanuts. Especially in fertilizer application methods, existing peanut sowing machine adopts centralized fertilizer application, which is not favorable for root system absorbing and using fertilizer, and not favorable for high yield and bumper harvest of peanuts. Excessive fertilizer easily leads to rotten seeds, burn of seedlings, and rotten fruit.

4.3 Harvesting performance of peanut harvester needs further improvement Domestic peanut harvesting machines are various. According to function perfection degree, peanut harvesting machine can be divided into three types: (i) peanut digger, only performing digging operation without function of separating soil and laying peanuts; (ii) peanut digging and harvesting machine, having function of digging, separating soil and laying fields; (iii) combined peanut harvester, having complete function of digging, separating soil, conveying, picking, cleaning, and gathering peanuts[18]. The peanut digging plow is simple in structure and can be used together with small four-wheel tractor or walking tractor. The drawback is single function and it fails to satisfy mechanical operation demands of many links in the peanut harvesting. In comparison, the peanut digging and harvesting machine has great improvement and can complete process of peanut digging, separating soil, and laying peanuts, but it still needs manual picking. At present, the search and design of combined peanut harvesting machine are still at the early development stage in China, and most machines and tools have problems of low working efficiency, high power consumption, low picking rate, and twining of peanut plants. Besides, rapid development of peanut harvesting machinery is restricted by peanut varieties, peanut plants, soil properties, soil moisture content, and residual film.

At present, the State provides great financial subsidies for crop grains and fine seeds, but it pays little attention to small crops like peanuts. Peanut harvesting machines are mainly manufactured by small and weak enterprises. Few large enterprises are engaged in manufacture of peanut machinery. As a result, there are problems of shortage of research and development funds, weak independent research and development ability, and low level of process, equipment and technologies, low level repetition and mutual imitation, lack of planning and reasonable labor division in industries. These problems seriously hinder integration of peanut agronomy and agricultural machinery and restrict research and development of peanut harvesting machinery.

4.4 Peanut seed shelling machine has the problem of high breaking rate of peanut pods or seeds The peanut picking machine can be divided into semi-feeding type and full-feeding type. At present, semi-feeding peanut picking machine is highly adaptable, can pick wet and dry peanut tendrils, has low power consumption, and can be used together with small tractor. Besides, it brings little damage to peanut tendrils. After picking peanuts, peanut tendrils remain neat and can be directly used as high quality feed for animal husbandry. The drawback is low working efficiency and possible missing picking and repeated picking. By contrast, the full-feeding peanut picking machine is light in weight and easy to move, so it needs few operators and the production efficiency is high. However, the full-feeding peanut picking machine also has problems of high power consumption, unclean picking, incomplete separation of tendrils, and high peanut breaking rate. Now, the peanut shelling machine is mainly sold for processing peanuts after shelling, so there are few enterprises engaged in manufacturing shelling machine for peanut seeds. The shelling machine for peanut seeds has problems of high breaking rate, seed coat shedding, and low germination rate[26], and thus it needs further improvement.

5 Recommendations for developing simplified peanut agronomy and agricultural machinery

5.1 Increasing government fund and scientific research input The development of peanut harvesting machinery in China still remains at early stage. Research and development, achievement transformation, experiment demonstration and popularization need policy guidance and large fund input. All the time, the government at all levels attaches greater importance to production mechanization of grain crops than industrial crops such as peanuts. With implementation of policy of subsidy for purchasing agricultural machinery, the production and application of agricultural machinery by agricultural machinery production enterprises and peanut planting farmers has obtained considerable development. The mechanized cultivation of peanuts experiences the process from simple agricultural tools to present combined farming operation. Because peanut harvesting machinery, especially combined peanut harvester, is complex in structure, difficult in manufacture, and high in costs, the price is relatively high. In line with existing rural economic conditions, it is recommended that government at all levels should provide financial support for farmers buying and using agricultural machinery, bring into full play the guidance of the policy of subsidy for purchasing agricultural machinery, stimulate farmers' enthusiasm to the maximum extent, and guide farmers to get onto the road of whole-process mechanization of peanut production.

5.2 Optimizing industrial distribution and realizing large-scale and standardized production of peanuts At present, the

situation of small and decentralized land parcels has seriously influenced China's agricultural machinery development process. Moderate scale operation of land has become the fundamental requirement for developing mechanized agriculture and modern agriculture. With enlargement of land area, the advantages of agricultural machinery will be fully manifested and peanut planting will become more standardized. It is recommended to establish and improve social service system for peanut planting as per industrialized and regionalized requirements. Besides, it is recommended to strengthen training of large peanut planting farmer households and family farms, to improve their production skills and operation and management level. For example, it is recommended to bring into full play their radiation and promotion functions, implement unified distribution, unified seed supply, unified field management, and unified harvesting, to realize close combination of peanut agronomy and agricultural machinery[27].

5.3 Close cooperation of multi-disciplinary and multi-field experts When taking traditional indicator (such as high yield and high oil content) as breeding and cultivation objectives, agronomic experts should also strengthen breeding of peanut varieties with erect peanut plants, centralized fruiting, high peg strength and long harvest time. Besides, they should consider planting modes suitable for peanut machinery. For agricultural machinery experts, they should actively communicate and exchange with agronomic experts, propose corresponding requirements for peanut varieties and cultivation systems, and improve adaptation of agricultural machinery to agronomy as much as possible. Agricultural machinery should be suitable for agronomic requirement, while agronomy should make suitable changes for adapting to mechanized operation and take agricultural machinery as support, to promote development of agricultural mechanization and agricultural modernization. For modern peanut production, agronomy and agricultural machinery departments should get rid of traditional ideas, adjust research concepts, mutually support and adapt, closely combine, and integrate together, and make joint effort to improve mechanization level of peanut production, to realize modernization of peanut production.

5.4 Strengthening top level design and improving organization and coordination The integration of peanut agronomy and agricultural machinery should accord with the agricultural mechanization development goal of 2020, and it is required to formulate scientific regulations, organization and implementation schemes. It is recommended to strengthen leadership, establish special organization to make top level design, reinforce coordination of management departments, and mutual cooperation of scientific research institutions, and establish coordination mechanism for integration of agronomy and agricultural machinery. Besides, it is recommended to make overall plans and coordinate to solve problems and difficulties in the process of agricultural mechanization development, and assist agronomy and agricultural machinery departments in formulating procedures for simplified cultivation technologies of integration of peanut agronomy and agricultural machinery and carefully organizing the implementation.

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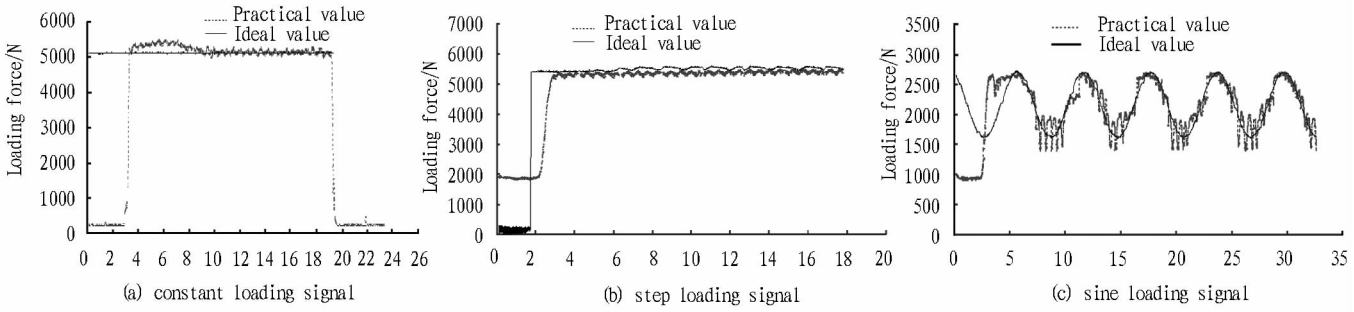

Fig. 4 Loading force response curve

5 Conclusions

(i) As an example for 4WD tractor of model JS-754, the maximum steering resistance torque in the process of steering has been analyzed and calculated under the conditions of hard ground and soft ground. The torque is 1568.87 Nom and 1761.82 Nom, respectively. (ii) The loading system of hydraulic steering-by-wire test-bed has been adopted by the method of electro-hydraulic loading. In addition, the electro-hydraulic loading test bench has been set for the loading simulation experiment of steering resistance. (iii) In the loading test bench, the resistance loading simulation experiment has been carried out. And the input signal of loading control system includes constant signal, step signal and sine signal which can be used to simulate tire lateral resistance when tractor steers under different working conditions. (iv) The maximum error of signal tracking is 3.1%, the average error is 2.3%, the maximum delay time is 1.1s. Hence, the electro-hydraulic loading system has the ability of high stability and following performance.

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