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Research Article

Paddy Eco-characteristics and High Yield Technology in Enshi Mountain Areas

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Abstract: Owing to the effect of topography, morphology and climate, the paddy ecosystem of Enshi mountain areas has significant mountainous characteristics. The climate of paddy fields shows a law of obvious vertical distribution. What's more, the paddy ecosystem is complex in soil type, excessive in pests and diseases (especially, blast is distributed widely and its harm is serious), frequent in low temperature damage, low in intensive degree and difficult in tillage management. According to these characters, some technical measures were advanced to gain high yield and stable production of rice in Enshi mountain areas. First, the producer should choose varieties with anti-disease (mainly blast), hardy (cool late and autumn winds) and high-yield and do rational distribution with them. Second, we should take a series of steps to suit the needs of local conditions, including dry raising and thin planting, thrown dry rice nursery, semiarid cropping, rational rotation, scientific control of fertilizer and water and so on. Third, farmers should control diseases and insects comprehensively.

Keywords: Enshi mountain areas, high yield techniques, paddy ecological character, paddy wetland

INTRODUCTION

Rice field not only bears the mission of grain-production, but also has the ecological service functions of climatic regulation, nitrogen fixation and emission reduction, purification of water and soil, soil fertility maintenance and so on (Ma *et al*., 2002). Literature material shows that the ecological value of rice field is much higher than its product value, that's to say, rice planting can maintain food security as well as the sustainable development of social economy (Zhou *et al*., 2009). Enshi Tujia and Miao Autonomous Prefecture, located in the west-south of Hubei Province, at the east edge of our country's second ladder, belongs to a part of *Yunnan-Guizhou Plateau*, is completely a mountain area, which extends from 108°30′12″E to 110°38′8″E and stretches from 29°7′10″N to 31°24′13″N. 220 km from east to west, 260 km from south to north, the city has a total area of 24061.25 km^2, which is also one of the places of the process of China's development. The rice planting area in Enshi is about 77250 ha for an average year and the rice-growing is focused on single cropping medium rice. It is of great value in the protection of ecological environment and the development of local economy to analyze the eco-characters of this place and study its relative production techniques.

MATERIALS AND METHODS

The climate there demonstrates a vertical distribution significantly: Enshi belongs to warm and humid semi-tropical monsoon climate areas, whose general climate characters are rain and heat coming in the same quarter, warm and wet, with little severe cold in winter and little bitter heat in summer, with abundant rainfall, heavy humidity, uneven distribution of precipitation, little sunshine and frequent droughts and floods. Its climate zone is broadly divided into six types: pinggu climate located in regions less than 500 m above sea level where is humid and warm in winter; low mountain climate located in regions 500 to 800 m above sea level where is warm and humid; two-alpine climate where is mild and humid with an altitude of 800 to 1200 m; middle mountain climate where is warm, cool and wet, with an altitude of 1200-1500 m; alpine high maintain climate located in regions 1500 to 2300 m above sea level with frigid and with high humidity; old alpine climate is alpine and with excess humidity, which located in regions more than 2300 m above. According to the Meteorological Bureau's data of Enshi Prefecture from 1961 to 1980, the average annual sunshine hours of Enshi mountain areas are 1168-1630

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h, the percentage of sunshine is 26 to 37% and the total annual amount of radiation in Yangtze River Canyon is 98 kcal/cm^2 and the remaining are 85 to 95 kcal/cm^2, where is one of the regions of our country with least sunshine hours and solar radiation. Due to high mountains' barrier function, low hills become "warm winter zones", with annual average temperature of 16-17°C, annual accumulated temperature (above 10°C) of 5000-5500°C, the average temperature of January and July is 4.5-6.0°C and 26-28°C. The frost-free period is 280d, which are basically suitable for plant growth throughout the year. Two-alpine area (Lichuan), the annual average temperature and annual accumulated temperature (above 10°C) are 12.7 and 3876.1°C, respectively. The mean January and July temperature is 1.8 and 23.3°C, respectively and the frost-free period is 233 days. So the growing season is relatively shortened. Then to the area with an altitude of 1819 m, the annual average temperature dropped to 7.8°C, the accumulated temperature is only 2224.4°C, the average temperature of January and July are -3.3 and18.2°C and the frost-free period 203 days. The main crop combine is ripe once a year. The wind speed also tends to increase with increasing elevation. And the feature of three-dimensional agriculture is very significant there.

As a result of the uplift of warm temperature by Wuling mountain in southeast, Enshi mountain has become one of the rainy centers of Hubei Province. The annual rainfall is more than 1300 mm, increasing with the increase of altitude, locally up to 2114 mm. About 76% of the annual rainfall centralizes in April to September, which can meet the needs of the rice production. The annual precipitation is greater than evaporation there except for Badong County and the moist coefficient (K) is 1.2 to 1.4. Except for Badong County, the annual average relative humidity is greater than 80%, with no significant difference in four seasons, thus the hydration of the soil is strong and the annual variation is small.

There exists many types of paddy soils; the distribution of paddy area at different elevations is olive shape slightly: According to the Soil and Fertilizer Station of Enshi Autonomous Prefecture Bureau of Agriculture's soil survey data in 1979, the statewide area of paddy soils is 77, 250 ha, accounting for 3.2% of the total soil area and for 25.5% of the total arable land. They are spread throughout the whole prefecture and the distribution at different altitudes is slightly olive, mainly centralizing in the two-alpine and low-hill Pinggu areas ranging from 501 to 1200 m above sea level (Table 1), accounting for more than 80%. In Enshi Prefecture, the parent materials that formed the rice soil are diverse, among which mudstone and limestone developed bigger area of paddy soils, each accounting for about 25%; paddy soils formed from parent materials such as quartzite, quaternary clay, purple rock, river alluvial materials and so on account for 10.5, 7.6, 14.2 and 11.0%, respectively. Water condition in argillaceous rock and purple rock areas are better, but poor in limestone areas.

Table 1: Paddy area in regions with different altitudes in Enshi mountain areas (1979)

Elevation (m)	Area (hm^2)	(%)
Below 300	470.67	0.61
300-500	8022.00	10.38
501-800	29920.87	38.73
801-1200	34750.93	44.98
1201-1500	4037.67	5.23
Above1500	47.93	0.06
Total	77250.07	100.00

There are five sub-categories of paddy soils of the region: flooded sterile paddy soil, retention paddy soil, gley paddy soil, swamp paddy soil and lateral seepage paddy soil, with 34 soil genus, up to 99 soil species. Among the 5 sub-categories, the area of gley paddy soil is 74381.00 ha, accounting for 73.63% of the total area of paddy soils; among the 34 soil genus, red and yellow soil pelite mud field, yellow-brown argillaceous rock mud field, purple mud field and damp soil field area account for the total paddy soil area of 10.43, 10.29, 10.29 and 9.52%, respectively; among the 99 soil species, purple mud field, yellow flat sand mud field, flat sand mud field, yellow mud field and yellow-brown mud field area, account for 7.57, 7.55, 6.76, 5.01 and 4.47% of the total area of paddy soils, respectively.

The plant diseases and pests are with a great variety: Rice blast, sheath blight, false smut, cloud-shaped disease (brown leaf blight), plant hopper (mainly brown plant hopper) and borers (rice stem borer and yellow stem borer, leaf roller, etc.) occurred widely and seriously.

This region, where rice blast causes serious damage and has a wide range of popularity, is one of the well-known ill districts. According to the identification of Enshi Prefecture Academy of Agricultural Science, Enshi owned a total of 8 groups and 35 physiological races in the 1980s, among which ZB group is the dominant population, ZG1 is the dominant race. And in the 1990s, there were a total of 8 groups and 38 physiological races, among which ZC group is the dominant population, ZB group comes second and G5, B5, C13 are the dominant races. In Enshi Prefecture, the perennial occurrence area of rice planting of this disease is about 22,000 ha and the perennial loss due to rice blast hazard is 10 to 20% generally, up to 40-50% when severe, partial plots even with not a single grain reaped.

The law of disease occurrence in regions with different altitudes has been summarized as follows. Rice blast in two alpine rice areas with an altitude of 800-1200 m is most severe, while in low mountain area below 800 m and mountain rice area above 1200 m are relatively light. But in recent years, there is an

Table 2: Characters of new rice varieties which is better suited to different altitude in Enshi

Variety	Approved year	Approved grade	Suitable region	Main characters and traits
Yixiang 107	2008	Provincial	At elevations below 800 m	Good quality, high yield and blast resistance
Yixiang 208	2010	Provincial	At elevations below 800 m	Good quality, high yield and blast resistance
Leyou 107	2010	Provincial	At elevations below 800 m	Good quality, high yield and blast resistance
Quanyou 128	2008	Provincial	At elevations below 800 m	High yield and blast resistance
Quanyou 99	2009	Provincial	At elevations below 800 m	High yield and blast resistance
Fuyou 325	2003	National	At elevations below 800 m	High yield, blast resistance and wide suitability
II you 264	2009	National	At elevations below 800 m	High yield, blast resistance and wide suitability
Zhong 9 you'en 62	2009	Provincial	At elevations below 800 m	High yield, blast resistance and wide suitability
II you'en 22	2007	Provincial	At elevations below 800 m	Good quality, high yield and blast resistance
Jinyou 107	2010	Provincial	At elevations 800-1000 m	High yield and blast resistance
Shenyou 9734	2010	Provincial	At elevations 800-1000 m	Good quality, high yield and blast resistance
II you 80	2005	Provincial	At elevations 800-1000 m	High yield, blast resistance and hardy
Guyou 92	2009	Provincial	At elevations 800-1000 m	High yield, blast resistance and hardy
Quanyou 2689	2008	Provincial	At elevations 800-1000 m	High yield and blast resistance
Mian 5 you 142	2011	Provincial	At elevations 800-1000 m	Good quality, high yield and blast resistance
Bijing 37			At elevations above 1200 m	High yield, blast resistance and hardy

aggravating trend in low mountain area below 800 m. Sheath blight in the rice area of low mountain area below 800 m was most grave, gradually reducing with the elevation increasing, but there is an increasing trend in recent years in the high-mountain rice area with an altitude of 800-1200 m. False smut and cloud-shaped disease (brown leaf blight), however, gradually increases with the elevation increasing. On the aspect of pest, the occurrence and damage period of most pests (such as plant hoppers and borers) gradually delays with the elevation increasing and the extent and universality of regularity aren't strong, but are related to the year. However, some pests (such as rice negative mud worm) occur mainly in the rice area of or more than two-alpine regions.

Frequent low temperature hazard: The spring rise of temperature there is instable, late spring cold happens frequently, autumn cools quickly and the drop of autumn temperature is not stable and low temperature hazard often occur (Yang *et al*., 2004). At the rice areas above an altitude of 800 m it performs particularly. For instance, only in Lichuan, the total rice production in 2002 cut by about 30% than the conventional year, due to low temperature in fall ("cold dew wind").

In addition, in the low mountain rice area below 800 m, there are also problems of summer drought and late summer autumn drought.

HIGH YIELD PRODUCTION TECHNIQUES OF RICE IN ENSHI MOUNTAIN AREAS

Rational distribution of disease-resistant varieties: High-quality, high yield, disease-resistant seed is the basis to achieve high and stable yield of rice and selecting this kind of seed is also an effective measure of controlling pest and disease damage within the scope of economic allowance. Due to the complexity of terrain and climate conditions, the selected varieties should be diversified.

Through years of effort, the local agricultural technicians have selected and introduced many rice seed varieties suitable for local rice cultivation with different altitudes. At present, the main cultivars that are suitable for rice planting in low mountains below 800 m are: Yixiang 107, Yixiang 208, Leyou 107 Quanyou 128, Quanyou 99, Fuyou 325, II you 264, Zhong 9 you'en 62 and II you'en 22; the seed mainly suitable for rice planting in the 800-1200 m high mountain are varieties-Jinyou 107, Mian 5 you 142, Shenyou 9734, II you 80, Guyout 92 and Quanyou 2689 etc.; and the appropriate varieties grown in 1200 m alpine area are: Bigeng 37 and so on (Table 2).

Relative high-yield culture techniques:

Sowing timely and cultivating strong seedlings: Late spring cold in early spring may easily cause seed putrescence; cold dew wind in two-alpine area will cause coveting green and late-maturing and immaturity when serious; and in low hills, summer drought and late summer autumn drought will reduce seed setting rate. By sowing timely, these problems can be effectively avoided.

To water rice-nursery it (at elevations below 800 m) is appropriate in the early to middle April in low mountain area to sow and the seedling age is 30 days around; in two-alpine area (altitude, above 800 m) it is appropriate in mid-April to late to sow and the seedling age is 30-35 days. To dry rice-nursery (including thrown dry rice nursery): in low hills, it is appropriate in the mid-March to sow and the seedling age is within 35 days; it is appropriate to sow in late March to early April, in two-alpine region and the seedling age 40 days or less.

Planting with rational spacing and setting up high-yield seedlings frame: It is appropriate to plant 150000-225000 holes/hm^2 in rice areas of low mountain and the row and hole spacing can be 33.3×20.0 to 26.7×16.7 cm, thus the basic seedling number is 900000-1200000/hm^2; in two-alpine region or above, planting 225000-300000 holes/hm^2 is appropriate and the line and hole distance is 26.7×6.7 to 20.0×16.7 cm and the basic seedling number 1200000-

1500000/hm^2. The wide-narrow row spacing method can also be used. In the rice area of low hills, specification of (26.7 cm + 40.0 cm) /2×16.7 cm can be used, while for two-alpine area or above, (20.0 cm + 33.3 cm) /2×16.7 cm is suitable. Lining to the east-west is ideal. And the hole amount and basic seedling number of every hectare should be ensured when applying thrown dry rice-nursery.

Fertilizing with formula and doing water management scientifically: According to the result of soil fertility examination, various scientific and rational fertilizer formulations are made up. In general, fertilization of the total nitrogen rate, appropriate for medium fertility plots, is about 150 kg/hm^2 and the proportion of N:P:K fertilizers is 1.0:0.6:1.2; while the proper amount of Zn fertilizer is about 22.5 kg/hm^2. It is required that the base fertilizer is sufficient, the top dressing early, the panicle fertilizer cleverly and the granulated fertilizer is complemented appropriately. Base fertilizer, mainly farm manure, accounts for about 60% of total nitrogen application; but panicle fertilizer is focused on the readily available nitrogen. It is necessary to apply Zn fertilizer of 30-45 kg/hm^2 in the cold-socked field and rot mud field in which stump sitting (zuo dou) usually happens. In addition, it is efficient to employ lime of 1500-2250 kg/hm^2 to improve the physical and chemical properties of soil and prevent the phenomenon of stump sitting.

Promoting dry rice-nursery and thrown dry rice-nursery techniques in rice areas of two-alpine area or above: Dry rice-nursery and thrown dry rice-nursery have the advantages of three "early" (early-planted, early-onset, early maturing), three "saving" (labor-saving, water-saving, seeding field -saving), two "high" (high yield, high efficiency) and extensive seedling age range, etc. They also can effectively increase the effective accumulated temperature of rice to make seedlings lower and healthier and improve their cold-resistance and rooting ability. Besides, increasing the effective accumulated temperature will result in the condition that the seedlings are not easy to sit stump after being transplanted, have more white roots, revive fast, tiller early and the plants' maturity may advance 7 days, thus the yield can be increased by 750 kg/hm^2.

The implementation of the dry nursery and thrown dry rice-nursery techniques need some necessary conditions. The first one is choosing a flat terrain with sunny leeward side, handy water source, deep, fertile and loose soil and manageable condition as the land seedbeds. It is best to choose a vegetable garden. Then, it is the preparation of nutrition soil used for thrown dry rice-nursery. The key is to enrich the band soil, sterilize and adjust the acidity. The third one is sowing timely, sparsely and evenly. The fourth one is the management of seedbed, mainly insulating moisture and heat in the seedling stage, controlling temperature and insulating moisture in the one to two leaf stage, conducting domestication, high-control, top dressing and root promotion in the three-leaf stage and after the four-leaf stage, controlling seedlings, promoting root and tiller, preventing excessive growth and cultivating dwarf-robust seedlings. The fifth is controlling and preventing the major pests and diseases of drought seedlings. The sixth one is doing well in management of field period.

Promoting semi-dry rice cultivation techniques in potential marsh low-yielding fields: There are a total of 3.6732 million hectares of potential marsh rice fields in Enshi Prefecture, accounting for 47.5% of the total paddy soil area. It includes four types: original/secondary latent development, swamp (mud field) and cold soaked field. The saturation or over-saturation of water in paddy soil offers the necessary condition to the occurrence of latent layer (blue mud layer). Due to the long-term saturation of soil water, there is mainly reducing action in the soil, causing restore of harmful substances (ferrous ion, hydrogen sulfide and organic acids, etc.), lack of effective nutrient, low water temperature and soil temperature, bad soil structure and so on.

Semi-dry cultivation techniques take the field surface into furrow deformation to achieve long-term soil moisture reconcilement, warming, oxygenation and stable manure. The essential is to plant rice on the ridge and improve the relative position of rice tiller node, thereby reducing or avoiding the hazard of cold immersion water. The multi-year pilot demonstration results showed that the average income of rice applying semi-dry cultivation techniques was1875 kg/hm^2 more than that of flooded level culture, increasing 45%.

Comprehensive prevention and control of diseases and pests: The principle of prevention in rice diseases and insect pests is preventing first and preventing and controlling comprehensively. Control early and control it when the hazard is not serious. The main strategies is preventing actively before the occurrence of diseases and pests and preventing and controlling the hazard of diseases and pests actively after the occurrence of diseases and insect pests. There are some methods being used to prevent and control diseases and pests, such as agricultural controls, physical controls, biological controls, chemical controls and so on.

The agricultural control measures including: Selecting resistant varieties, changing seeds every 3 to 5 years, reducing snout moth's larva in fields, tilling timely after harvesting and killing moth pupaes and timely removal of straws and weeds at the edge of the field. What is more, putting fields in the sunshine at later tillering stage, fertilizing on the basis of soil testing and fertilizer recommendation technique,

adjusting sowing date to avoid the peak-hour of brown plant hopper's migration and spread of viruses and covering the fields with insect net are also effective agricultural controls.

The physical control methods mainly depend on light trap. Trembler grid lamps and black light lamp are used frequently to kill *Suppressalis*, *Tryporyza incertulas*, Rice plant hoppers and rice leaf rollers to achieve the aim of prevention and cure.

The biological control measures include raising ducks in fields, protecting natural enemies (frogs, spiders, beetles, lacewings, parasitic wasps and so on) and using biological pesticides (*Bt • matrine*, *Bacillus*, *Bacillus cereus*, *Kasugamycin*, *Jinggangmycin • ningnanmycin*) etc.

The chemical control measures mainly including: Rice blast, using medicines to prevent and control leaf blast in the initial lesion and using medicines to prevent and control rice blast in the break early heading stage, the medication apply for 2 to 3 times. We should choose single agent of *Tricyclazole* or *Isoprothiolane*, do not use the compound agent in rice blast. The dosage: 70% *Tricyclazole wettable* powder about 450 g/hm^2, or 40% *Isoprothiolane* EC1500 mL/hm^2, or 2% *Blasticidin* EC was 900-1200 mL/hm^2.

Banded sclerotial blight: In cultivation, we should be attention to proper thin planting, little nitrogen fertilizers, timely and moderate keep field drying. The radical principle of chemical control techniques are using once of pesticides in the late tillering to booting stage, heading period gap. Dosage: 20% *Jinggangmeisu* WP 750-900 g/hm^2, or 10% *Jinggangmeisu • waxy* bacillus agent 2250 mL/hm^2.

False smut and cloud disease: The key point of chemical control techniques is applying fertilizers once from 5 to 7 days before heading and heading stage. Dosage: 30% *Difenoconazole • propiconazole* EC 300 mL/hm^2, or 43% *Tebuconazole suspension* agent 225 mL/hm^2, or 10% *Jinggangmeisu • waxy* Bacillus agent 2250 mL/hm^2. For rice cloud disease, as long as control rice blasts, can also control its occurrence and damage.

The class of rice plant hoppers, the key point of chemical control techniques: when young nymphs of rice plant hopper apply chemicals during its peak, at the same time, plant field should be maintain certain water and apply chemicals in the foot of rices. Dosage: 25% *Buprofezin* WP 450-750 g/hm^2, or 10% *Imidacloprid* WP 150-300 g/hm^2, or 5% *Butane-fipronil* EC 750-900 mL/hm^2.

The class of snout moth's larva, especially *Cnaphalocrocis medinalis*, the key point of chemical control techniques is adopting spraying between *Cnaphalocrocis medinalis* egg hatching peak and the 2 instar larvae of the peak. Dosage: 1.8% *Abamectin* EC 600-750 mL/hm^2, or 40% *Chlorpyrifos* EC was 1800 mL/hm^2, or 40% *Profenofos* EC 1200-1500 mL.

Improving middle-low-yielding rice farmland: Potential marsh type (wet and flooded type) rice field is the main type of lower middle yielding rice soil. Main improvement measures:

- Engineering measures, namely ditching and drainage, improving soil permeability, excluding the accumulated water on the surface of the secondary potential field logging, avoiding water seepage and inflow from all around and leading to the cold spring water
- The semi-dry cultivation techniques
- Biological measures, in rotational conditions, selecting the adaptable species
- Rational fertilization-appropriately adding phosphate and potassium fertilizer and supplementing zinc fertilizer
- Scientific management of water-timely exposing the paddy field to sun

Vigorously promoting small machinery appropriately used in mountain area: The mountainous terrain in Enshi is sophisticated and the tillage is of great difficulty and the labor of rice industry is with high costs. The development of small agricultural machinery should strongly be supported and actively guided to facilitate the combination of R&D sector and the agricultural research and extension department and promote small machinery suitable for mountain operations, such as micro-cultivators, seedling plug (cast) machines, ridging machines and harvesters, to reduce the labor intensity and continuously improve the economic benefits of rice industry.

DISCUSSION

The paddy field itself is a kind of constructed wetland. In Enshi, the "winter bubble fields" are actually a number of large and small mini-reservoirs, planting traditional glutinous rice and local tall varieties which are not afraid of flooding and of long growing seasons, having no need of drainage and storing water throughout the year. Since the 1970s, due to the excessive pursuit of highly-yield and the promotion of hybrid rice, the planting area of traditional glutinous rice and local tall cultivars dropped sharply, resulting in that the vast majority of "winter bubble fields" became arid or semi-arid. How to coordinate the relationship between yield and environmental protection is a subject worthy of study. To restore and protect the paddy wetlands, some advice was specially recommended:

- Referring to the protection of cultivated land, set the red line of paddy wetland area through

legislation as indicators of the government's assessment of achievements and intensify the propaganda at the same time.

- Encourage paddy water storage throughout the year, establish glutinous rice and traditional local varieties grown test area or protected area and give some "green subsidies" to farmers according to water storage area (Tian, 2010).
- Rational fertilization, appropriate additional phosphate and potassium fertilizer and supplementary zinc fertilizer.
- Strengthen the research of relative technology of paddy wetland especially “winter bubble fields” and coordinate the relationship between yield and environmental protection.
- Scientifically adjust the industrial structure, change the mode of development and explore a new path to achieve the sustainable development of the national economy of the region.

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