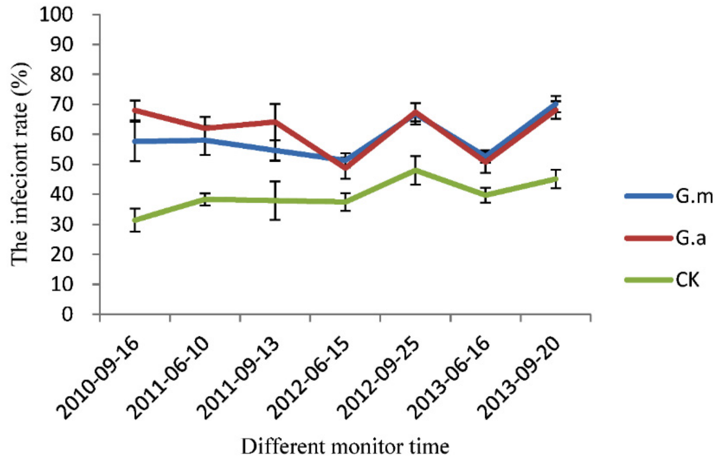

Fig. (2). Effect of AMF in different areas on infection rate.

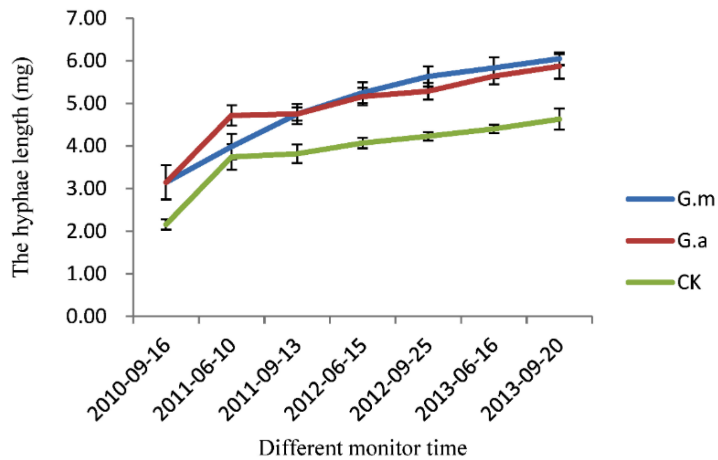

Fig. (3). Effect of AMF in different areas on hyphae length.

other, therefore, the mycorrhizal infection rate is higher. In the next year of September after and before the arrival of the rainy season, the change of rainfall and temperature is not suitable for the growth of mycorrhizal fungi, mycorrhizal fungi spores dormant at this time, therefore, mycorrhizal infection rate is low before the rainy season coming in June.

3.3. The Influence of Mycorrhizal Inoculation on Hyphae Length

The hyphae length reflects the arbuscular mycorrhizal effects on plant rhizosphere [10]. Unit of rhizosphere soil of mycelium length is larger, the more conducive to the root system on soil nutrients and moisture absorption and transportation, the more can promote plant growth and improve the resistance of plants (Fig. **3**).

Monitoring results show that: from 2010.09.16 to 2013.09.20 as the extension of inoculation time, hyphae length in different treatment area present the same rule, hyphae length appear as G.m G.a CK, Inoculation can improve the hyphae length in soil, up to more than 40%. Inoculation area and control area with hyphae length are increased with the growth time, inoculation area and control area reached significant difference, but hyphae length between G.m and G.a had no significant difference in plant rhizosphere. By tracking hyphae length change of different treatments of rhizosphere soil, the monitoring results show that various growth after four years had been established a stable arbuscular mycorrhizal symbiosis.

3.4. Correlation Analysis Between Hyphae Length and Olsen-P

Mycelium length can be considered to be an important index of mycorrhizal infection efficiency, research has confirmed that mycorrhizal inoculation can increase plant absorption of phosphorus [11]. Unit mass of mycelium length, the greater the soil contained in the hypha and secretion, the more the more soil aggregate (size is less than 0.25 mm), the easier it is to form stable soil glue particles. Under the condition of the wild field, to verify whether mycelium length of soil effective phosphorus in plant rhizosphere effect, by use of EXCEL of mycelium length can be obtained by seven sampling test analysis and linear regression equation of effective phosphorus content (Table **1**).

The analysis found that there is a linear correlation between various rhizosphere mycelium length and effective phosphorus content. Correlation coefficient values from 0.1032 to 0.1032, correlation coefficient of G.m and G.a area was larger than CK area, but there is no significant difference

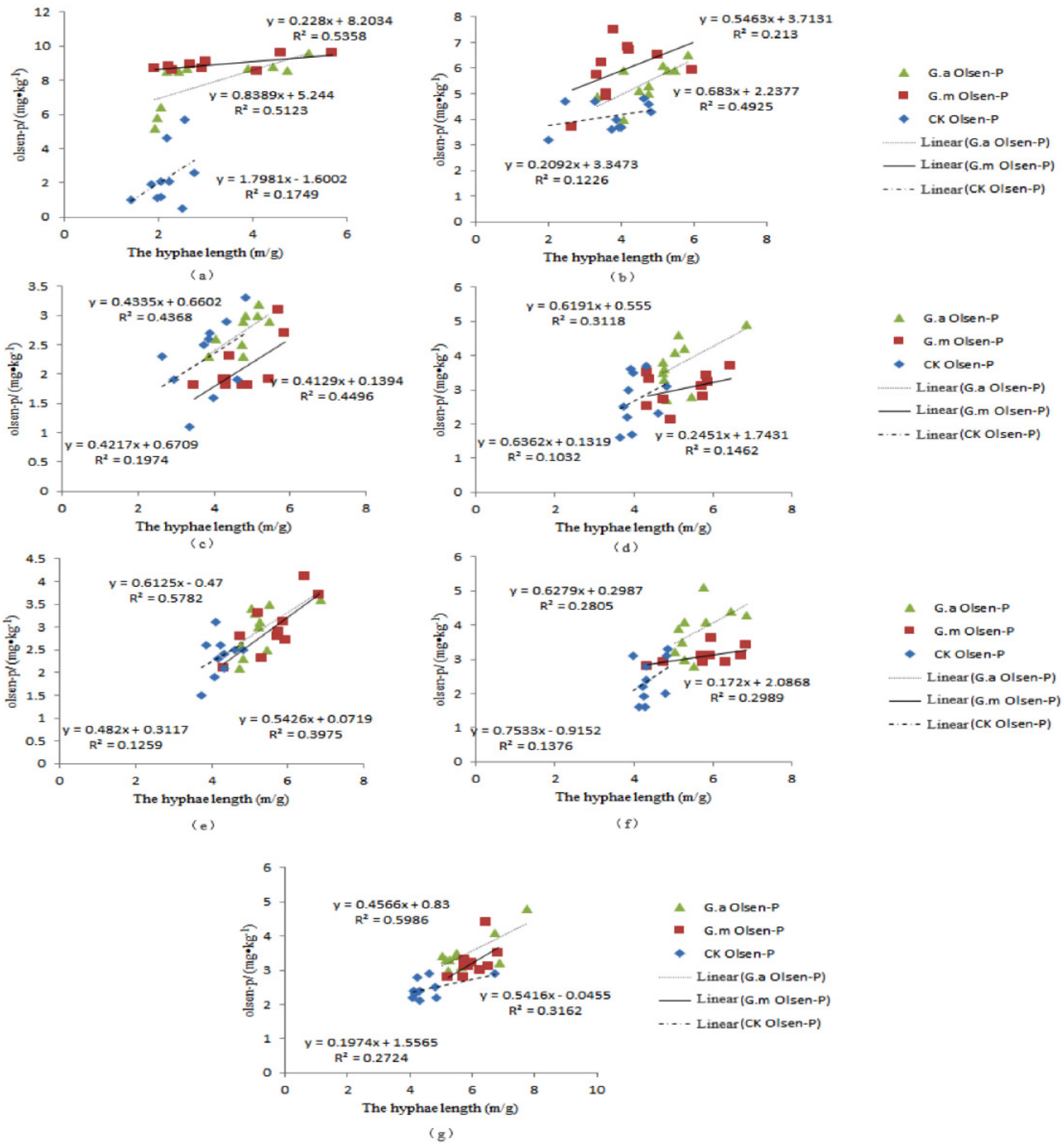

Fig. (4). Correlation analysis between hyphae length and Olsen-P in different time.
(**a**) 2010-09-16, (**b**) 2011-06-10, (**c**) 2011-09-13, (**d**) 2012-06-15, (**e**) 2012-09-25, (**f**) 2013-06-16 and (**g**) 2013-09-20.

between G.m and G.a. Correlation coefficient value of G.m and G.a varies changed dramaticly and in CK area change is relatively stable, correlation coefficient value of G.m and G.a area appeared as w-type fluctuations, generally had smaller values in the trough when in June each year, and rise to wave in September, comparing CK correlation coefficient value varies was small but also presents the trend of w-type fluctuations.

The different treatments of linear regression equation between rhizosphere mycelium length and effective phosphorus content was showed in Fig. (**4**), always reflected significant correlation in September, including the inoculation area (2010-09-16, G.m=0.732, G.a=0.716, $p<0.05$;2011-09-13, G.m=0.671, G.a=0.0.661, $p<0.05$; 2012-09-25, G.m=0.760, $p<0.05$; 2013-09-20, G.a=0.774, $p<0.05$) and totally emerged six significant difference. However, it had poor correlation in June, with only one significant difference appeared (2011-06-10, G.a = 0.702, $p < 0.05$). The CK area in all previous monitoring soil and there was no significant difference between effective phosphorus content and mycelium length, the reason

Table 1. The correlation coefficient between olsen-P and hyphae length of Amorphafruticosa L.

Monitor time	Treatments	Correlation coefficient	Monitor time	Treatments	Correlation coefficient
2010-09-16	G.m	0.732*	2012-09-25	G.m	0.760*
	G.a	0.716*		G.a	0.630
	CK	0.418		CK	0.355
2011-06-10	G.m	0.462	2013-06-16	G.m	0.547
	G.a	0.702*		G.a	0.530
	CK	0.350		CK	0.371
2011-09-13	G.m	0.671*	2013-09-20	G.m	0.562
	G.a	0.661*		G.a	0.774*
	CK	0.444		CK	0.522
2012-06-15	G.m	0.382			
	G.a	0.558			
	CK	0.321			

Notes: *means significant correlation at $p<0.05$ level, the same hereafter

could be underground hyphae network of mycorrhizal fungi accelerated activity with the arrival of the rainy season from June to September every year, the spore germination, root hyphae infect plant roots, after the rainy season with the decline of temperatures and less rainfall, underground hyphae network activity is reduced, mycorrhizal infection rate was decreased and root hyphae secretion is also reduced.

4. DISCUSSION

Through inoculated arbuscular mycorrhizal fungi on different treatments in Shendong mining area, mutual symbiosis formed between plants and mycorrhizal fungi, expanded the roots and the hyphae in contact with the soil, the inoculation plants absorb more nutrients than in the CK area plants. Experiments showed that the hyphae phosphorus absorption rate is about four times that of root hair, root hyphae can stretch to the root table 8 cm absorption of phosphorus in the soil, mycorrhizal hyphae can store a more phosphorus than absorbed by plant roots, phosphorus mainly inorganic phosphorus forms of transport in plants and transport rate of 2 mm/h, phosphorus transport in mycelium is in the form of polyphosphate particles [12-14]. As there is no diaphragm in arbuscular mycorrhizal fungi hyphae, phosphorus can transport within the root hyphae in two-way sides, and the transport rate could reached 20 mm/h, which was tenfold within the root rate and root makes external hyphae of soil phosphorus, it was able to be quickly transported to the root mycelia again by polyphosphate particles which are decomposed into simple inorganic phosphorus transferred to the host plant [15]. In the wild field experiment, the inoculation area and CK area plant rhizosphere absorb effective phosphorus ability differences reflected in the differences in plant biomass on the ground, survival rate, plant height, ground diameter and crown which were significantly better than CK area. This experiment was conducted in Shendong mining subsidence land area, soil effective phosphorus content was in lower level, the test results showed that the mycelium length and plant rhizosphere effective phosphorus content exist certain linear fitting, which supported the view that in some extent, under the condition of low phosphorus, efficiency of mycorrhizal infection is one of the leading factors of capacity difference in plant phosphorus absorption.

CONCLUSION

(1) In the wild field under the condition of inoculation of arbuscular mycorrhizal fungi promote various survival rate above 30%, and the inoculation can significantly improve the aboveground biomass of plants. The inoculation increased the ability of mycorrhizal fungi infect root, mycorrhizal infection rate is influenced by mining area climate conditions, presents the w-type fluctuations, before the coming of rainy season in June each year in the trough, and in September after the rainy season in the wave.

(2) Effective phosphorus content on different treatments in the rhizosphere and mycelium length appeared positive correlation, the inoculation area correlation coefficient is higher than CK area. Correlation coefficient and mycorrhizal infection rate change trend, show w-type fluctuations, and it is related to the rainfall in mining area, temperature and other weather conditions and underground hyphae network development.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

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