Effects of Groundnut Husk Ash-blended Cement on Chemical Resistance of Concrete

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Absract

The empirical investigation reported the effects of chemicals on the properties of concrete with cement partially replaced with Groundnut Husk Ash (GHA). The principal characteristic measured was the compressive strength of Ordinary Portland Cement (OPC) concrete and OPC/GHA concrete after curing in three chemical solutions ($MgSO_4$, NaCl and H_2SO_4) at 14, 21 and 28 days hydration periods. The results revealed that the OPC/GHA concrete performed best in most of the chemical solutions at 28 days hydration period with compressive strength values of 21.05N/mm^2 in $MgSO_4$ solution and 22.55Nmm^2 in NaCl solution. The study concluded that OPC/GHA concrete having proven resistant to magnesium sulphate and sodium chloride media would perform better in soils containing $MgSO_4$ and NaCl.

Key words: Blended cement; groundnut husk ash; magnesium sulphate; sodium chloride; sulphuric acid; compressive strength; durability of concrete.

Introduction

Cement concrete is the most widely used building material due to its satisfying performance in strength requirements and its ability to be moulded into a variety of shapes and sizes. However, the durability aspects of concrete, including resistance to chemical attack (which results in volume change, cracking of concrete and the consequent deterioration of concrete) are matters of concern. Concrete durability as defined by Reddy and Marcelina (2006) is the capability of concrete to resist deterioration from freezing and thawing, heating and cooling, the action of chemicals such as deicers and fertilizers, abrasion, or any other environmental exposure. Over the years, many waste materials like fly ash and ashes produced from various agricultural wastes such as palm oil waste, rice husk ash, corncob ash, millet husk ash, groundnut husk ash have been tried as pozzalana or secondary cementitious materials. These supplementary cementing materials play an important role when added to Portland cement because they usually alter the pore structure of concrete to reduce its permeability, thus increasing its resistance to water penetration and water related deterioration such as reinforcement corrosion, sulphate and acid attack. According to Dhir and Byars (1992), the construction industry has more firmly accepted the use of secondary cementitious materials with Portland cement in recent years and this is reflected in various current standards worldwide. This in turn requires that any shift in the durability potentials of these blended cement concretes be established.

Prasad, Jain and Ahuja (2006) studied the performance of plain and blended cement mortar cubes of 50mm, exposed to sodium sulphate solution of varying concentrations of 1.0%, 1.5%, 2.0%, 2.5% and 4.0%, for up to 24months. The degree of deterioration was evaluated by strength reduction and by visual inspection. Results of the study indicate that the rate of deterioration increased with increase in sulphate concentration for both plain and blended cement. The sample prepared by fly-ash blended cement shows less deterioration in comparison with the plain cement for all concentration and all time of exposure. The performance of blended cement over plain cement is attributed to the pozzolanic reaction which produces additional calcium silicate hydrate CSH gel, blocking existing pores and altering the pore structure, thus causing substantial improvement in strength and impermeability.

Cheng (2000) showed that chloride in concrete can be either dissolved in pore solution or chemically and physically bound to the cement hydrates and their surfaces. The former is referred to as free chloride and the latter as bound chloride. Only the free chlorides dissolved in the pore solution are responsible for initiating the corrosion process. The best way to reduce the risk of chloride penetration is to produce concrete of low porosity and concrete in which the mineralogy of the hydrates leads to a reduction in the mobility of the chloride ions. Kamang, Audu-War and Datok (2001) reported that the use of Pulverized Fuel Ash (PFA) as partial cement replacement in concrete results in slight decrease in the alkalinity of the pore solution. It was further reported that the use of PFA cement is much better than Ordinary Portland Cement (OPC) in terms of its ability to reduce the supply of chloride ions. Mehta (1998) reported that ordinary Portland cement with pulverized fuel ash or blast furnace slag showed a lower chloride migration rate than ordinary Portland cement. Bouzouba and Fournier (2001) found that addition of pozzolans or slag increases the corrosion-resisting characteristics of concrete.

Mehta and Folliard (2002) showed that Rice Husk Ash (RHA) cement has improved resistance to acid attack, compared to OPC, as a result of the silica content of RHA which combines with the calcium hydroxide in cement and, reduces the amount of cement susceptible to acid attack. Similarly, Rahmani and Ramzanianpour (2008) stated that acid attack generally occurs when the calcium hydroxide is attacked vigorously; the attack can be mainly an acid attack or a combination of acid followed by a salt attack. It was concluded that the performance of mortar and concrete containing trass and ultra fine filler was better than the control mixture in sulphuric acid solution, mainly due to its low porosity, dense packing and high silica content.

Groundnut has been gaining increasing importance as a cash crop in several tropical countries, particularly Nigeria where the greatest production is in the northern parts of the country, for example, Adamawa, Kano, Bauchi, Katsina, Plateau and Borno states (Roland, 1985). Unfortunately however, the shell or husk is considered to be waste product with little or no use, after the groundnut is extracted.

Solid waste has to be disposed off to prevent pollution. Currently, husk solids are used as fuel for fire. After combustion, about 5% ash by weight of husk is produced. Since the ash does not have sufficient nutrients to be used as fertilizer, hence alternative means of disposing the ash is required. Ordinary Portland cement (OPC) is expensive and unaffordable to large portion of the world's population. Its high cost is due to the industrial process of manufacture and, its transportation from point of production to areas or site for usage (Neville, 2000). Since OPC is typically the most expensive constituent of concrete, the replacement of proportion of it with Groundnut Husk Ash (GHA) may improve concrete affordability particularly for low-cost housing in developing countries like Nigeria. The use of GHA may contribute not only to the production of concrete of a higher quality and lower cost but also lead to reduction of carbon dioxide (CO_2) emission from the production of cement. The partial replacement of cement with GHA may also result in lower energy consumption associated with the production of cement. It is in view of this that effort is geared towards investigating the performance of GHA-blended cement concrete, in aggressive environment, with the following objectives:

- To investigate the chemical and physical properties of Groundnut Husk Ash.
- To determine the effects of magnesium sulphate, sodium chloride and sulphuric acid in curing water on the compressive strength of Groundnut Husk Ash concrete.

Materials and Method

Groundnut husk used for this research was sourced from Lantang North L.G.A. of Plateau State. The husks was collected in bags and transported to Jos and later moved to the National Metallurgical and Development Centre (NMDC) Jos, where the burning, grinding and the determination of the chemical analysis were carried out. Consequently, the ashes were collected in bags and were taken to the Concrete and Structural Laboratory of the Department of Building, University of Jos. The sieve analysis, moisture content and the specific gravity were carried out on GHA at the Soil Mechanics Laboratory of the Department of Building, University of Jos. The results of chemical analysis, physical properties and sieve analysis of GHA are presented in Tables 1, 2 and 3 respectively.

Dangote brand of Ordinary Portland Cement was used as the main binder. It conforms to type 1 cement as specified by BS 12 (1978). The fine aggregate used for this research was natural quartzite dredged from river and was air-dried before use. The particle size distribution conducted on the fine aggregate shows it to fall within zone 2 of BS 882 part 2 (1973) with a specific gravity of 2.66, while the coarse aggregate was gravel with a specific gravity of 2.58. It was air dried and particles smaller than 4.75mm were removed.

Mixes

A concrete mix of ratio 1:2:4 was adopted for the production of concrete cubes at water / cement ratio of 0.6. Cement content was replaced at 10% with GHA. The adopted substitution level of 10% was based on previous work conducted by Alabadan, Njoku and Yusuf (2006) which recommended 10% as the most suitable replacement level for OPC/GHA concrete. Batching by volume was adopted. 150mm x 150mm x 150mm cubes were produced for the tests. A total of 72 cubes were cast. They were subsequently cured in different media of magnesium sulphate at 15% concentration; sodium chloride at 15% concentration; and sulphuric acid at 5% concentration. The choice of the percentage concentration of chemicals used as curing media was based on a similar research carried out by Kamang et al (2001). Some of the cubes were cured in water and used as reference point for comparison. All the cubes were cured for hydration period of 14, 21 and 28 days respectively. Average of three cubes was crushed for each test. The results of the compressive strength are shown in Tables 4, 5, 6 and Figures 1, 2, 3, 4.

Table 1: Physical properties of Groundnut Husk Ash

Moisture content	0.43%
Specific gravity	1.85

Table 2: Chemical Analysis of Groundnut Husk Ash

Constituents	Percentage
SiO_2	34.2
Al_2O_3	12.042
Fe_2O_3	14.0
CaO	14.3
MgO	2.0
Na_2O	0.048
K_2O	15.46
P_2O_3	2.1
MnO	0.36
SO_3	0.64
LOI	4.85

Table 3: Sieve Analysis of Groundnut Husk Ash

Sieve size	Retained		Percentage passing
	Weight (g)	Percentage (%)	
300 microns	0	0	100
212 microns	0	0	100
150 microns	0.2	0.2	99.8
75 microns	29.8	29.8	70
Tray	70	70	0

Table 4: Compressive Strength of OPC and OPC/GHA cured in Water and 15% solution of Magnesium sulphate ($MgSO_4$)

	Compressive strength(N/mm^2)	
Description	Water	15% $MgSO_4$
	14days	
OPC Concrete	20.15	16.80
OPC +10% GHA	14.75	15.15
	21 days	
OPC Concrete	21.65	18.25
OPC +10% GHA	16.15	17.50
	28 days	
OPC Concrete	23.90	20.15
OPC +10% GHA	19.26	21.05

Table 5: Compressive Strength of OPC and OPC/GHA cured in Water and 15% Solution of Sodium Chloride (NaCl)

Description	Compressive strength(N/mm^2) Water	15% NaCl
	14days	
OPC Concrete	20.15	19.00
OPC +10% GHA	14.75	18.10
	21 days	
OPC Concrete	21.65	20.05
OPC +10% GHA	16.15	20.45
	28 days	
OPC Concrete	23.90	22.50
OPC +10% GHA	19.26	22.55

Table 6: Compressive Strength of OPC and OPC/GHA cured in Water and 5% Solution of Sulphuric acid (H_2SO_4)

Description	Compressive strength(N/mm^2) Water	15% H_2SO_4
	14days	
OPC Concrete	20.15	14.00
OPC +10% GHA	14.75	10.25
	21 days	
OPC Concrete	21.65	15.65
OPC +10% GHA	16.15	13.95
	28 days	
OPC Concrete	23.90	17.55
OPC +10% GHA	19.26	17.00

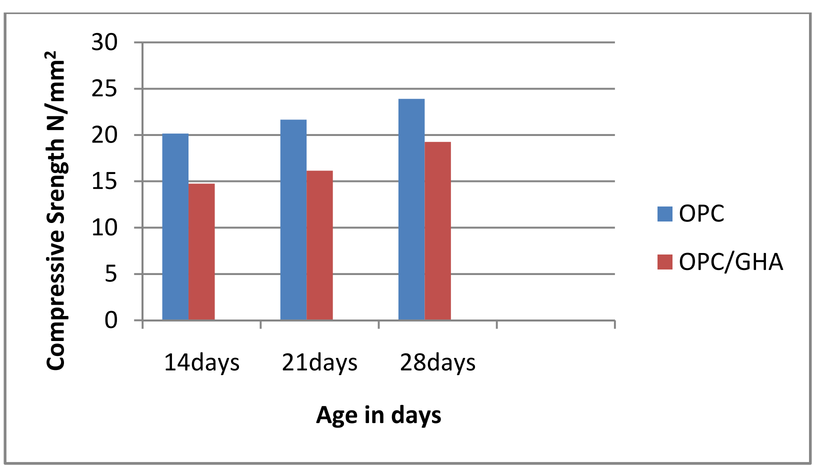

Figure 1: Compressive strength of OPC and OPC/GHA cured in water

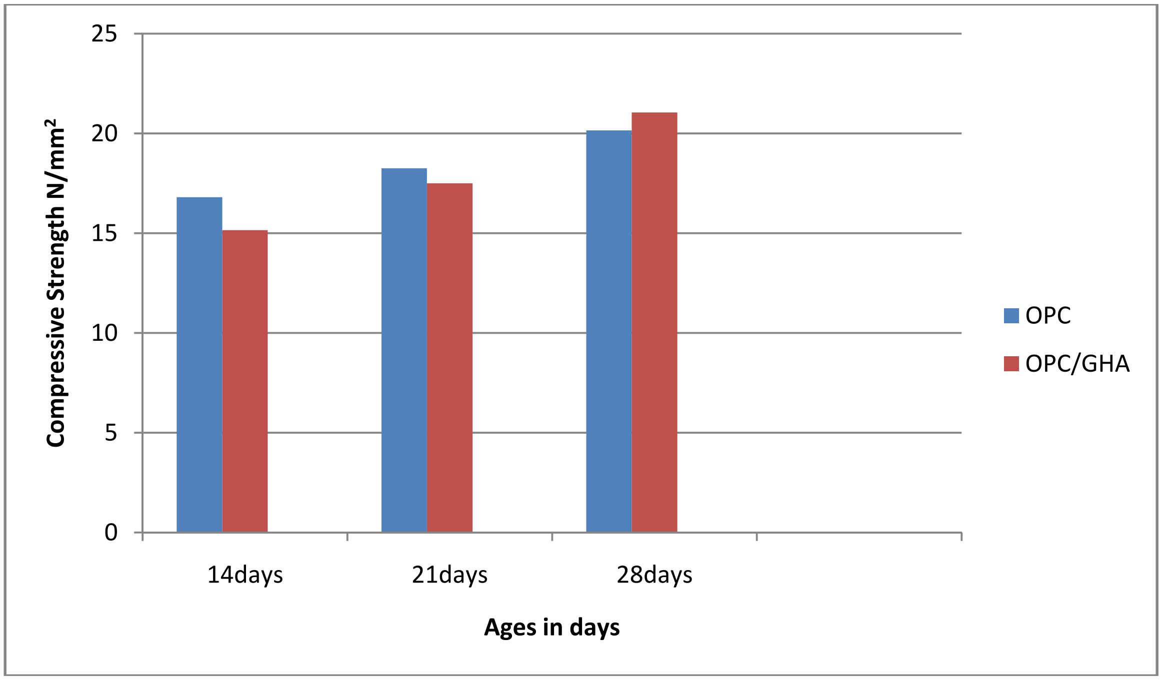

Figure 2: Compressive strength of OPC and OPC/GHA cured in 15% $MgSO_4$ solution

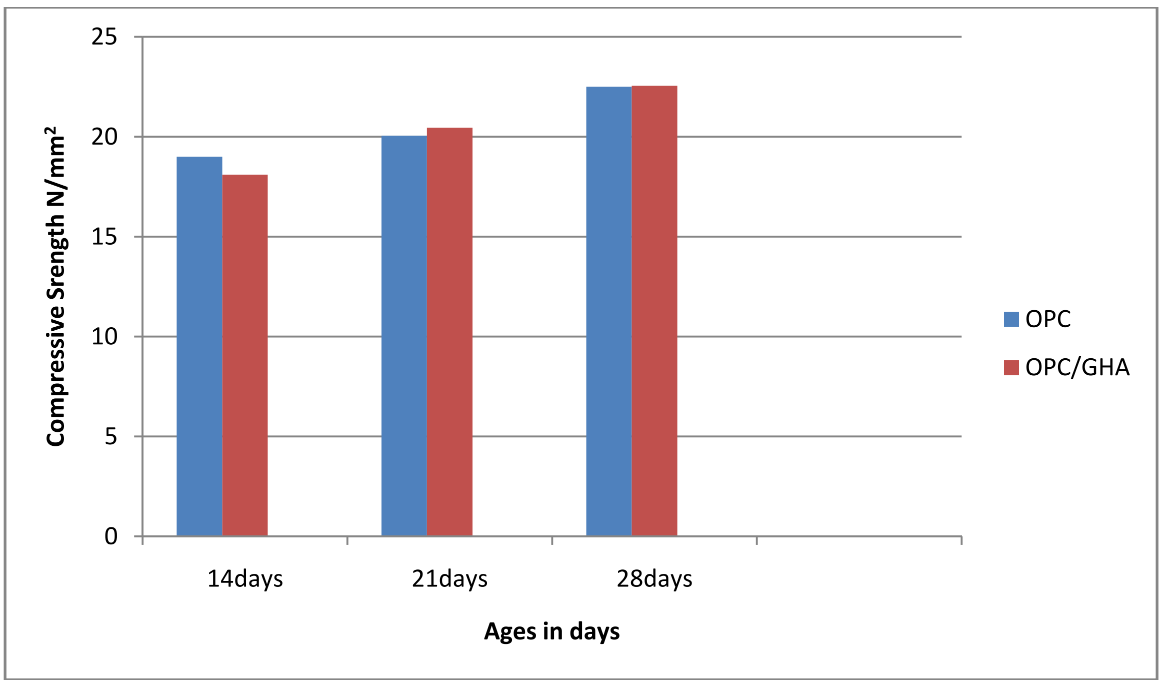

Figure 3: Compressive strength of OPC and OPC/GHA cured in 15% NaCL solution

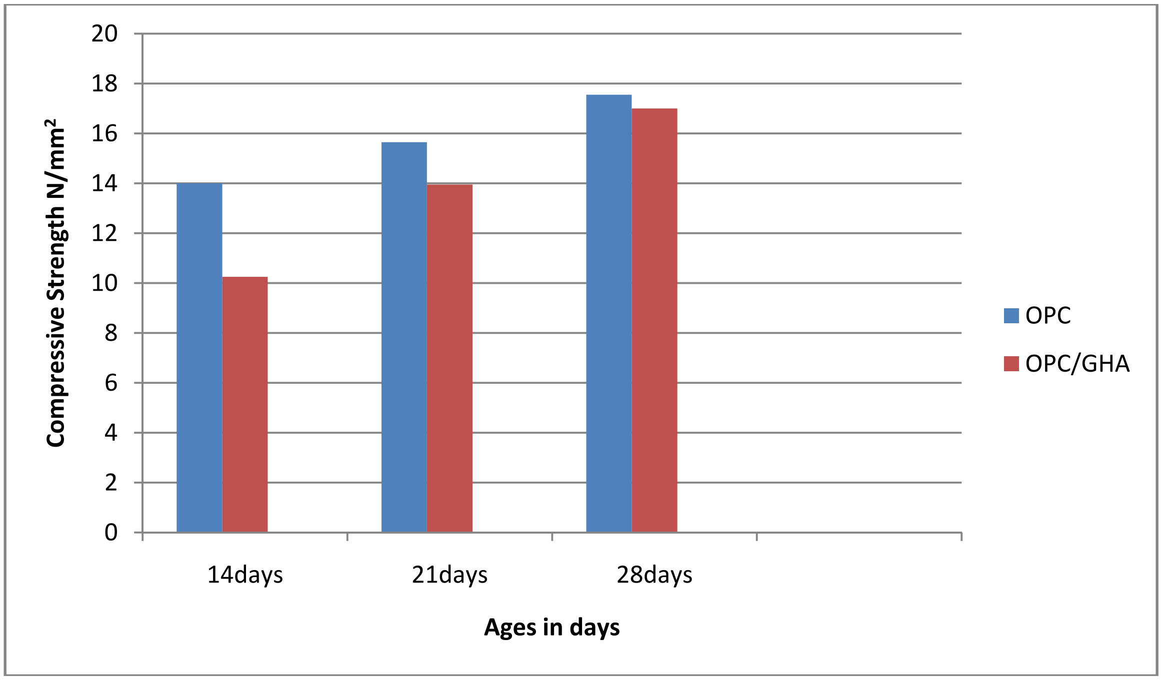

Figure 4: Compressive strength of OPC and OPC/GHA cured in 5% H_2SO_4 solution

Results and Discussion

Tests carried out have shown the specific gravity of GHA as being 1.85. This value is far less than 3.15 for Portland cement. The value is close to the value reported by Kamang *et al* (2001) which was 1.90 for Pulverised Fuel Ash. The result of the sieve analysis of the Groundnut Husk Ash shown in table 2 indicates a grading that is similar to that of Ordinary Portland cement as presented by Neville (1981).

The results of chemical analysis of groundnut husk ash are shown in Table 3. The total percentage composition of Iron oxide (Fe_2O_3 = 14.0%), aluminium oxide (Al_2O_3 = 12.042%) and silicon dioxide (SiO^2 = 34.2%) was found to be 60.242%. This is less than 70% minimum required for pozzolana (ASTM C 618-94, 1994). This reduces the pozzolanicity of the Groundnut Husk Ash. The percentage composition of silicon dioxide (34.2%) and iron oxide (14.0%) were within the range specified by Alabadan *et al* (2006). However, the percentage composition of aluminium oxide was not in agreement with the work of Alabadan *et al* (2006). The loss on ignition meets the maximum of 12% requirement stipulated by ASTM C618-94 (1994). The magnesium oxide was also within the range specified by ASTM C618-94 (1994).

Values obtained as initial setting time for OPC and OPC/GHA pastes were 2 hours 45 minutes and 3 hours 27 minutes respectively. Final setting time values were obtained for OPC and OPC/GHA pastes as 3 hours 15 minutes and 4 hours 39 minutes. The setting time values obtained were within the recommended range of 30 minutes to 10 hours stipulated by (ASTM C191-1992).

Compressive Strength

The compressive strength result of OPC and OPC/GHA cured in 15% magnesium sulphate and in water is showed in Table 4 and Figure 2. The result shows loss in compressive strength of OPC concrete cured in $MgSO_4$ solution at 28 days over that of OPC concrete cured in water. The OPC/GHA concrete shows no sign of strength loss, rather there was increase in its value at 28 days. This may be attributed to the reaction between magnesium sulphate solution and cement paste forming gypsum ($CaSO_4 – 32H_2O$) and ettringite ($3CaO – Al_2O_3 – 3CaSO_4 – 32H_2O$). Formations of both compounds are associated with the expansion that can diffuse degradation and cracks of the OPC concrete leading to strength reduction. The expansion reactions are due to the presence of calcium aluminate hydrates. The use of OPC/GHA produces concrete of lower C_3A content and lower permeability which can prevent the strength reduction from occurring in OPC/GHA concrete.

Table 5 and Figure 3 show the compressive strength results for OPC and OPC/GHA cured in 15% sodium chloride solution and in water. These results are similar to that obtained by karisnamoothy (1996) who worked on a similar material (Portland cement-fly ash concrete) and reported a strength gain in OPC/PFA concrete over OPC concrete. The reason for the strength loss in OPC and strength gain in OPC/GHA could be that the GHA made the concrete more impermeable for solution penetration. This may be the reason for the strength gain in the OPC/GHA concrete. The high permeability coefficient of the OPC concrete may have resulted in the weakness, porosity and loss of strength recorded.

Table 6 and Figure 4 show the compressive strength results for OPC and OPC/GHA cured in 5% solution of sulphuric acid and in water. From the result both the OPC and OPC/GHA performed poorly in sulphuric acid solution, but the OPC concrete suffered most. The reason can be attributed to the presence of void in the OPC concrete and hydrated cement gel (Neville, 1981). Also, the lower strength recorded by the OPC concrete may be due to the reaction between lime in the OPC and sulphuric acid. The lime in OPC concrete is higher when compared to the lime-pozzolanic reaction in the OPC/GHA concrete. This may have contributed in the reduction of strength in the OPC concrete.

Summary of Findings

Sieve analysis showed that 70% of GHA passed through the 75 microns sieve size. This implied that the ash used had the same fineness level with cement.

The GHA has moisture content value of 0.43% and specific gravity of 1.85. The value of the specific gravity of GHA used was far less than that of cement which is 3.15 (Neville, 1981).

The initial setting time and the final setting time were within the recommended range of 30 minutes to 10 hours stipulated by (ASTM C191-1992). These results agree with the findings of Ikpong (1993) which reported increase of setting times of OPC-RHA paste over the plain cement paste.

There were reductions in compressive strength of OPC cured in magnesium sulphate solution and sodium chloride solution at 28 days over that of OPC cured in water. The OPC/GHA showed no sign of strength loss in chemical solutions rather there was increased in its values at 28 days. The compressive strength values of OPC concrete at 28 days in $MgSO_4$ and NaCl were 20.10N/mm^2 and 22.50N/mm^2 respectively. While that of OPC cured in water is 23.90N/mm^2. The compressive strength values of OPC/GHA cured in water, magnesium sulphate and sodium chloride at 28 days were 19.26N/mm^2, 21.05N/mm^2 and 22.55N/mm^2 respectively.

The OPC concrete and OPC/GHA concrete suffered strength loss in sulphuric acid solution, but the worst hit was the OPC concrete at all the hydration period of 14, 21 and 28 days.

Conclusion

The experimental work has been devoted to evaluate the performance of Groundnut Husk Ash blended cement on the chemical resistance of concrete. From the result of the tests and analysis carried out, the following conclusion can be drawn: The Groundnut Husk Ash blended cement concrete haven proven resistance to magnesium sulphate and sodium chloride media would perform better in soils containing $MgSO_4$ and NaCl.

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