AN INVESTIGATION OF POSSIBLE CROSS–INOCULATION AMONG SOME STRAINS OF COWPEA *Rhizobium* AND DIFFERENT COWPEA GROUP CULTIVARS[1] /

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Resumen

Diecisiete variedades de frijol de tipo Rhizobium *isoladas de varias leguminosas en Nigeria fueron investigadas con objeto de examinar su eficacia y la posibilidad de cruzamiento con frijoles de tipo TVU 201 y TVU 1190, "fijol lima", "gandul", "frijol alado" y mani, en condiciones naturales tanto como en invernadero.*

Por medio de número de nódulos, peso seco y cantidad total de nitrógeno fijado por cada planta, se descubrió que la mayoria de las variedades se revelaron eficaces con los frijoles TVU 201, TVU 1190, "gandul" y "frijol alado". En condiciones de invernadero, solo algunas variedades se revelaron eficaces con mani y "frijol lima" y ninguna formó nódulos en condiciones naturales.

En el invernadero, la variedad 11 mejoró la producción de los tipos TVU 201, TVU 201, TVU 1190, "frijol lima", "gandul", "frijol alado" y mani del 60% 100%, 70%, 140%, 370% y 61% respectivamente, mientras en condiciones naturales en el campo la variedad 9 aumentó la fijación de nitrógeno en los frijoles tipos TVU 201, TVU 1190, "gandul", "frijol alado" y mani, de un 66%, 163% 251%, 74% y 64% respectivamente en comparación con las leguminosas que no sufrieron inoculación.

Estas variedades particularmente fértiles y eficaces pueden ser de gran utilidad en la producción en cantidad comercial de inoculantes en el afán de mejorar la fijación de nitrógeno con leguminosas tropicales.

Introduction

The importance in the humid tropics of nitrogen fixed symbiotically by *Rhizobium* in association with legume species cannot be overemphasized, as farmers still rely largely upon shifting cultivation as a major means of restoring and sustaining soil fertility, and fertilizer usage is alarmingly but understandably small. The fertilizer problem is worsened by the fact that the cost skyrockets every year, leaving the tropical farmer, who sometimes suffers from protein malnutrition, with the only reasonable alternative of a rotational or multiple cropping system in which legumes are included as a source of plant nutrients.

Even where fertilizers are available, a substantial proportion of N applied to soils is often unavailable to crops because of denitrification and leaching losses; these processes may even give rise to potential secondary problems of air and water pollution. Besides, the energy-consuming relatively inefficient chemical fixation of N by the Haber –Bosch process contributes only 2.2 x 10^{10} kg/yr N to the global

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fixed N pool compared to 9.1 x 10^{10} kg/yr provided by the more efficient, natural, biological N fixation (1). It is in view of these fertilizer problems that many developing countries are currently considering detailed extensive studies of the *Rhizobium* – legume symbiosis as a means of increasing crop yields and providing adequate plant protein without the input of the costly and often unavailable fertilizer N.

Of the seven cross-inoculation groups of the *Rhizobium*–legume associations (2), the cowpea is predominantly and almost exclusively found in the tropics. Therefore, the provision of a competitive, effective, and highly promiscuous cowpea rhizobial inoculant for use on food legumes in the tropics is an inescapable pre-requisite of our drive for increased biological N fixation and plant protein production in the developing countries.

Hence, this preliminary investigation examined different strains of cowpea *Rhizobium* for effectiveness and possible cross-inoculation against some common and widely cultivated tropical legumes. The screening was done in both greenhouse and field plots to assess the strains which might be useful in selection of potential inoculants.

Materials and methods

Sources of rhizobia cultures. Fourteen of the rhizobia strains used were isolated from 14 varieties of cowpea cultivars which were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan. Three other strains of cowpea *Rhizobium* were isolated from cowpea plants at the University of Ife Teaching and Research Farm. Isolation of pure colonies from the legume nodules was performed according to the procedure of Vincent (3). All the 17 strains were found to be effective against cowpea cultivars when tested under laboratory conditions using the seeding agar technique of Vincent (3).

Sources of legume seeds. Cowpea TVU 201, cowpea TVU 1190, lima bean, winged bean, and pigeon pea were obtained from Dr. E. L. Pulver of the Grain Legume Improvement Programme, IITA, Ibadan. Groundnut seeds were bought from a local market in Ile-Ife.

Greenhouse Investigation: The mixture of coarse and fine sand used for the greenhouse investigation was collected from a stream near the University of Ife Commercial Farm. The sand was washed thoroughly with water and then with conc. HCl. The sand was later rinsed several times with water and then sun-dried. Its pH was 6.6 and calcium carbonate was added to raise the pH to 7. The sand was sterilized in the oven at 160°C for 48 hours, cooled, and dispensed into 250 plastic cups (each having a diameter of 9.7 cm and a depth of 9.7 cm) at the rate of 600 g per cup. Viable seeds of cowpea TVU 201, cowpea TVU 1190, lima bean, winged bean, pigeon pea, and groundnut, which had been surface sterilized with 95% ethanol and 4% H_2O_2, were planted in the sand-containing cups at the rate of 4 seeds per cup. Four replicates of each treatment were prepared. The cups were then arranged on a greenhouse bench in a completely randomized fashion. Each of the experimental treatments was inoculated with the appropriate *Rhizobium* strain (inoculant) which had been prepared by culturing a heavy suspension of the particular strains in a yeast extract mannitol (YEM) broth containing 1% sucrose, on a rotary shaker at 28°C for 3 days. A sterile plastic syringe was used for applying 8 ml of the rhizobial inoculant to each of the cups. Each of the nitrate control treatments received 5 ml of a 0.05% KNO_3 solution every other week. All treatments were amended with 5 ml of nutrient solution weekly (3), and 30 ml of sterile distilled water every 2 days. The greenhouse had an average temperature of 30°C.

The plants were harvested when 7 weeks old. They were sun-dried for 24 hours and later oven-dried at 80°C for 48 hours prior to the determination of their dry weights.

Field Investigation: As a follow up of the greenhouse studies a field investigation was carried out to assess the effectiveness of the test strains of cowpea *Rhizobium* under field conditions using the same legume cultivars. The field plot used at the Teaching and Research Farm of the University of Ife, at Ile-Ife, was selected because of its suspected low or no rhizobial count, since there was no history of legume cultivation on the site. After site clearing the plot was rid of organic matter as much as possible in order to discourage increase in inorganic nitrogen as a result of organic matter mineralization during the period of experimentation.

The plot (24.4 m x 14 m) was divided into 20 subplots to accommodate 20 randomly allocated treatments of 17 different rhizobial inoculants, 2 nitrogen fertilizer levels, and one uninoculated treatment. Each of the 20 subplots was analysed for its pH value, organic carbon, total nitrogen, P, Ca, Mg, K, Mn, and Na contents. The legume seeds were planted in rows, 50 cm apart, with 25 cm spacing. Four seeds were planted per stand with the addition of 10 ml of the appropriate broth inoculant. The two fertilized subplots were treated with 71.4 kg and 142.8 kg of ammonium nitrate/ha/wk, respectively. Ten days after planting, the seedlings were thinned to 2 per stand. Each of the 17 rhizobial treatments also received peat-based inoculants 18 days after planting. The peat-based inoculant was prepared by adding turbid rhizobial culture to sterile finely divided peat in the ratio of 1:2 ($^{v}/w$). The peat culture was kept at 25°C to cure for 72 hours and then allowed to mature for another 7 days before use. The peat-based inoculant was applied by mixing the inoculant with dry soil from the particular subplot in the ratio of 1:10 ($^{w}/w$), and applying the inoculant soil mixture to the base of the young plant.

The one meter path between subplots and the guard rows of each treatment prevented cross-contamination, and there was no rainfall during the period of the investigation. Each subplot was moistened with 25 litres of water every day. At the age of 6 weeks all the plants were sprayed with Novacron 40' to control insect pests. The subplots were carefully weeded by means of a hoe.

Harvesting was done when the plants were 7 weeks old, by carefully digging up four randomly selected plants from within each of the rows. The nodules were examined, dried at 70°C for 48 hours, and then weighed. The plants were dried for 2 days at 80°C, weighed, and nitrogen was determined by the modified micro-Kjeldahl method (4).

Results

Greenhouse Studies. Based on nodule formation and plant dry weight, eleven of the seventeen strains tested were very effective against cowpea TVU 201. These were strains 1, 4, 5, 7, 8, 9, 10, 11, 14, 15 and 16, but strains 4, 5, 8, 9, 10, 11, 14 and 16 were particularly effective since each resulted in an average plant dry weight of 1.03 g compared to 0.64 g and 0.74 g of the uninoculated and the nitrate amended plants, respectively (Table 1). Generally, only strain 6 was poorly effective against cowpea TVU 201. On the other hand, strains 4, 7, 8, 10, 12 and 17 were particularly effective against cowpea TVU 1190,

Table 1. Yield of the various legumes grown under greenhouse conditions.

Rhizobium Strain No.	Dry wt of Plants, g					
	Cowpea TVU 201	Cowpea TVU 1190	Lima bean	Pigeon pea	Winged bean	Groundnut
1	0.92	0.68	1.20	0.41	0.53	0.83*
2	0.88	0.73	0.99	0.48	0.67	0.60
3	0.81	0.56	1.32	0.47	0.71	0.54
4	1.07*	1.09*	1.28	0.53	0.77	0.62
5	1.04*	0.66	1.30	0.51	0.82*	0.73
6	0.55	0.62	1.26	0.23	0.66	0.56
7	0.92	1.05*	1.31	0.44	0.79	0.73
8	1.02*	0.98*	n.d.	0.58*	0.74	0.77
9	1.08*	0.79	n.d.	0.61*	0.98*	0.90*
10	1.05*	0.97*	1.35	0.57*	0.74	0.86*
11	1.02*	0.84	1.57*	0.60*	0.96*	1.00*
12	0.91	1.20*	1.35*	0.63*	0.64	0.79
13	0.79	0.85	1.16	0.29	0.84*	0.63
14	0.96*	0.88	1.57*	0.51	0.39	0.84*
15	0.94	0.89	1.66*	0.35	0.70	0.71
16	1.01*	078	1.10	0.44	0.50	0.69
17	0.89	1.11*	1.36*	0.54	0.83*	0.67
Uninoculated plant	0.64	0.41	0.92	0.25	0.21	0.62
Nitrate-amended plant	0.74	0.72	1.03	0.30	0.63	0.56

* Treatments with significantly high dry wt at 95% confidence limit.

n.d. = not determined.
Each value is a mean of 4 replications.

giving an average dry weight of 1.07 g compared to 0.4 g of the uninoculated plant. However, most of the strains did not nodulate lima bean, and the reason for this ineffectiveness is not known. Only strains, 1, 2, 3, 11, and 12 were found to be fairly effective with lima bean. Despite the lack of nodules both the unresponsive and the uninoculated lima beans grew luxuriantly, suggesting a minimal nitrogen requirement by this legume.

In pigeon pea only five strains, namely 8, 9, 10, 11, and 12 produced significantly high plant dry matter with 100% increase in yield when compared with the nitrate amended plant. The five strains that were effective on winged bean, 5, 9, 11, 13 and 17, gave significantly high dry matter yield, ranging from 0.82 g to 0.98 g per plant, whereas the uninoculated winged bean yielded 0.21 g. As shown in Table 1, strains 1, 9, 10, 11, and 14 were very effective on groundnut while the remaining strains were only fairly effective or ineffective.

On the whole, sixteen and fifteen out of the seventeen strains effectively nodulated cowpea TVU 201 and cowpea TVU 1190, respectively, while only five strains each were effective against lima bean and groundnut and thirteen strains each nodulated pigeon pea and winged bean. It should be noted that all the nodulated legumes gave considerably higher yields than either the uninoculated or the nitrate amended plants, suggesting good response of the legumes to rhizobial inoculation.

Field investigation: The chemical characteristics of the 20 subplots are shown in Table 2. The pH values ranged from 5.2 to 6.1 and since an average pH of 5.5 is required for efficient nodulation in cowpea and groundnut (5), it could be assumed that the pH values of the subplots were favourable for rhizobial survival and infectivity. Except for the phosphorus and calcium concentrations, which varied significantly at the 5% level, the other chemical parameters did not exhibit significant variations from subplot to subplot. However, it could not be assesssed whether or not these soil properties influenced rhizobia infectivity and effectiveness in the various subplots.

Table 2. The pH, % organic carbon and nitrogen, and the concentrations of phosphorus, calcium, magnesium, manganese, potassium and sodium of the soil samples taken from the 20 subplots.

Treatments	Sub-plots	pH	organic C %	N %	P ppm	Cations (ppm)				
						Ca	Mg	Mn	K	Na
1	12	5.9	1.61	0.23	8.7	885	209	21	105	14
2	20	5.4	1.37	0.20	7.2	570	195	35	90	16
3	10	6.1	1.37	0.21	21.8	870	225	10	150	14
4	16	5.4	1.62	0.27	9.8	750	222	19	135	16
5	8	5.3	1.52	0.20	8.3	675	180	30	150	14
6	18	5.6	1.00	0.14	7.8	375	105	16	105	10
7	1	5.6	1.14	0.16	5.0	510	176	18	90	11
8	5	5.4	1.44	0.21	12.9	900	218	32	150	16
9	2	5.8	1.44	0.22	28.2	1200	240	10	150	19
10	13	5.9	1.39	0.18	6.0	615	147	13	120	12
11	17	5.3	1.52	0.25	9.2	750	228	47	105	21
12	6	5.6	1.00	0.11	4.2	300	165	48	210	24
13	14	5.4	1.61	0.22	8.2	825	230	23	120	16
14	11	6.0	1.37	0.18	8.0	645	173	23	150	12
15	3	5.7	1.76	0.26	18.8	1350	249	17	165	21
16	19	5.2	1.07	0.21	7.4	585	146	41	105	18
17	9	5.3	1.61	0.22	5.3	885	194	17	120	17
18	4	5.5	1.44	0.21	6.0	630	159	30	120	15
19	7	5.4	1.44	0.21	12.9	510	168	75	120	16
20	15	5.2	1.61	0.25	7.8	585	207	51	135	17
Mean		5.55	1.42	0.21	10.18	721	192	29	130	16
Standard deviation		0.27	0.22	0.13	6.13	252	37	17	29	3

None of the seventeen strains was effective on lima bean while groundnut had small but numerous nodules. On the basis of nodule dry weights, cowpea TVU 201 seemed to be most responsive to rhizobial inoculation, followed by cowpea TVU 1190, and to a lesser extent by winged bean, groundnut, and pigeon pea (Table 3). As observed already, under greenhouse conditions, lima bean which did not form nodules did not exhibit any symptoms of nitrogen deficiency, strongly suggesting again, a low nitrogen requirement by this plant. Pigeon pea was found to be less responsive to inoculation in the field than in the greenhouse, whereas the reverse was the case for groundnut, which on basis of nodule number gave a better response to inoculation in the field than the other cultivars tested.

The average dry weight and the total nitrogen content of the various legumes (except the unresponsive lima bean) are depicted in Tables 4 and 5. It can be observed from both Tables that the plant dry weights generally correlated with their nitrogen contents, as most of the treatments that gave significantly high dry matter yields also fixed significantly substantial amounts of nitrogen. Most of the strains were very effective on cowpea TVU 201, cowpea TVU 1190, and groundnut in terms of nitrogen fixation. At 5% level, there were significant differences in the nitrogen content of each of the legumes due to treatment effects, but it is also significant to note that these differences in both the plant's nitrogen content and the dry weight are well correlated with the results of the greenhouse studies.

Expectedly all the legumes responded more to 142.8 kg than to 71.4 kg of the fertilizer. However, winged bean was particularly responsive to nitrogen fertilization as an amendment of this legume with 142.8 kg of NH_4NO_3/ha/wk resulting in 4.49 g of dry matter yield and 161.6 mg N/plant, which were higher than the yields obtained when the plant was treated with any of the seventeen inoculants (Tables 4 & 5). The other legumes seemed to be more responsive to rhizobial than to nitrogen fertlization, with the exception of lima bean.

Table 3. Dry wt of nodules of 6 legumes inoculated with 17 strains of Cowpea *Rhizobium* on a field plot.

	Dry wt of nodules, mg/plant					
Rhizobium Strain No.	TVU 201	TVU 1190	Lima bean	Pigeon pea	Winged bean	Groundnut
1	8.6	20.5*	0	1.4	27.3	17.5
2	4.8	22.0*	0	1.9	52.5*	12.7
3	19.1*	4.9	0	0	14.6	17.7
4	10.8	5.9	0	1.5	26.3	3.0
5	15.8	17.6	0	3.2	51.1*	16.9*
6	6.8	14.0	0	4.1	13.2	8.9
7	16.2*	12.4	0	0	51.2*	19.6*
8	110.5*	115.5*	0	2.1	30.9	10.9*
9	330.6*	6.5	0	5.7*	63.8*	13.9*
10	20.4*	16.2	0	0	3.7	14.1*
11	2.7	1.3	0	3.5	34.9	10.8*
12	22.2*	5.2	0	1.8	30.7	9.7
13	8.8	5.1	0	1.3	33.0	7.5
14	4.7	14.1	0	5.3	31.8	1.5
15	63.0*	6.8	0	7.1	84.8*	14.8*
16	8.6	7.6	0	0	9.0	5.6
17	1.3	8.7	0	1.6	30.5	10.7*
Uninoculated plant	0	0	0	0	6.1	5.7
N – Level 1	2.7	1.5	0	0	4.4	1.9
N – Level 2	0	0	0	0	1.7	3.6

* Treatments with significantly high nodule wt at 95% confidence limit

Each value is a mean of 4 replications.

Table 4. Dry wt of the inoculated, uninoculated, and nitrate-amended legumes grown on a field plot.

Rhizobium Strain No.	Dry wt of plants, g/plant				
	TVU 201	TVU 1190	Pigeon pea	Winged bean	Groundnut
1	7.00	8.54	1.83	3.06*	12.50*
2	9.51	8.00	3.61	2.96*	13.75*
3	19.13*	10.50	1.59	1.81	10.23
4	11.32	14.02*	3.08	2.86	8.17
5	10.64	11.98	1.63	2.90	12.02
6	9.20	8.45	3.33	1.80	7.01
7	18.00*	10.88	3.22	1.91	13.78*
8	15.89*	16.18*	5.79*	1.83	11.58
9	24.83*	16.52*	6.50*	3.53*	11.51
10	6.66	10.29	2.92	2.11	13.48*
11	9.68	15.69*	1.57	2.88	15.52*
12	10.60	14.77*	0.91	2.22	3.96
13	12.42	12.91	2.14	2.57	8.11
14	6.66	16.55*	2.31	3.74*	14.76*
15	19.05*	16.41*	3.75	2.75	14.29*
16	8.13	7.56	1.68	1.24	11.36
17	9.31	11.80	7.31*	1.62	12.50*
Uninoculated plant	6.55	8.14	1.47	1.87	5.96
N – Level 1	9.70	8.52	4.17*	2.11	8.64
N – Level 2	10.83	13.51*	4.31*	4.49*	11.12

* Treatments with significantly high dry wt at 95% confidence limit.

Each value is a mean of 4 replications.

Discussion

Under greenhouse conditions strains 2, 4, and 12 nodulated all legumes except groundnut while strains 5, 8, and 9 were also effective on all the cultivars except lima bean; but strain 11 formed nodules on all the six legumes. In the field, strains, 5, 6, 8, 9, 14, and 15 were effective against all the legumes except lima bean. The lack of response of lima bean to any of the seventeen strains of cowpea *Rhizobium* under both greenhouse and field conditions suggests that lima bean may not belong to the same cross-inoculation group with the other legumes under investigation even though lima bean (*Phaseolus lunatus*) is included in the cowpea cross-inoculation group (6), a group that obviously requires better delineation. This lack of response by lima bean also suggests that this legume is not genetically or otherwise very closely related to the other readily nodulated plants.

It is to be noted that groundnut responded better to inoculation in the field than in the greenhouse, though the reason for this observation is not clear. However, the tremendous interplay of biological and chemical factors within the soil might enhance the processes of infectivity and nodulation. In addition, native rhizobia might play some role in the effectiveness of groundnut under field conditions as some of the uninoculated plants bore a few tiny nodules.

Cowpea *Rhizobium* strain 11 was found to be most promiscuous in the sand culture as it nodulated all the six legumes producing big effective nodules. However, this strain was less effective or promiscuous in the field as it fixed relatively substantial amount of nitrogen only in cowpea TVU 1190 and groundnut (cf Tables 1, 4 and 5). The comparatively poor performance of this strain in the field vis-a-vis the greenhouse might be due to poor competitive capacity in the highly heterogeneous soil.

On the basis of similar positive response to the various cowpea *Rhizobium* strains there seemed to be some kinship among cowpea TVU 201, cowpea TVU 1190, pigeon pea, winged bean, and groundnut, but the kinship was more pronounced between the

Table 5. Nitrogen content of the inoculated, uninoculated and nitrate-amended legumes grown on a field plot.

Rhizobium Strain No.	N content of plants, mg/plant				
	TVU 201	TVU 1190	Pigeon pea	Winged bean	Groundnut
1	218.4	193.9	53.1	95.2*	200.0
2	298.6	320.5	84.5	82.6	459.3*
3	645.1*	217.4	38.0	46.7	288.5
4	204.9	321.1	78.8	68.1	267.2
5	299.0	346.2	40.1	71.3	264.4
6	222.6	272.9	80.3	56.3	185.8
7	586.8*	312.3	63.4	64.4	424.4*
8	311.4	430.4*	145.3*	53.1	334.6
9	387.3*	419.6*	144.3*	94.3*	254.4
10	145.2	355.0	66.9	55.1	393.6*
11	211.5	478.5*	37.8	71.1	487.3*
12	243.8	281.6	11.7	72.6	118.8
13	280.7	488.0*	47.9	87.1	224.6
14	219.1	369.1	89.4	115.6*	354.2*
15	339.1	359.4	121.9*	76.6	344.4
16	222.8	174.6	53.6	51.2	311.3
17	216.9	220.7	206.9*	45.4	351.3*
Uninoculated Plant	231.3	159.5	41.3	53.9	155.0
N – Level 1	183.3	196.8	126.8*	90.1*	285.1
N – Level 2	255.6	556.9*	133.2*	161.6*	315.8

* Treatments with significantly high N content at 95% confidence limit.

two cowpea cultivars, probably due to the initial isolation of all the strains from cowpea plants.

A careful scrutiny of Tables 1, 4, and 5 shows cowpea *Rhizobium* strains 8, 9, 11, and 15 as the most consistently effective and promiscuous bacteria both in the greenhouse and in the field. For instance, in the field, strain 9 produced an increase of about 320% in the dry weight of cowpea TVU 201, while strain 11 increased nitrogen fixation by 200% in cowpea TVU 1190, when compared with the uninoculated plants. In the greenhouse, strain 11 enhanced the dry matter yields of cowpea TVU 201, cowpea TVU 1190, lima bean, pigeon pea, winged bean and groundnut by 60%, 100%, 70%, 140%, 370%, and 61% respectively over the yields of the uninoculated legumes (Table 1). Similarly, the use of cowpea *Rhizobium* strain 9 as an inoculant in the field boosted nitrogen fixation in cowpea TVU 201, TVU 1190, pigeon pea, winged bean, and groundnut by 66%, 163%, 251%, 74%, and 64% respectively (Table 5). These strains could therefore be subjected to further greenhouse and field studies with a view to using them eventually for producing commercial rhizobial inoculants in order to boost nitrogen fixation by food legumes in the humid tropics.

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INSTITUTO INTERAMERICANO DE COOPERACION PARA LA AGRICULTURA*

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En virtud de que el IICA ha adoptado el Sistema Internacional de Unidades, nos permitimos anotar a continuación para los autores y colaboradores de las Revistas Turrialba y DRELA, así como para otras series de publicaciones del Instituto, las siguientes reglas principales.

En 1960, la Conferencia General de Pesas y Medidas (CGPM) y la Oficina Internacional de Pesas y Medidas (BIPM) decidieron por unanimidad en París, sede del BIPM, crear un sistema internacional de unidades de pesas y medidas (SIU). En 1975 había ya 44 paises miembros del BIPM cuya tarea principal es asegurar la unificación mundial en torno del SIU. Hoy día los Estados Unidos de América e Inglaterra han adoptado también el uso del SIU.

Por ejemplo, el kilogramo es unidad de masa, y ya no de peso; el recurso al concepto de peso queda abolido, pues corresponde en realidad a la fuerza de atracción debida a la gravedad, y, por lo tanto, los cuerpos en el espacio interplanetario no tienen peso, pero sí conservan su masa. La unidad de fuerza es el newton (N), que corresponde a la necesaria para producir una aceleración de un metro por segundo sobre una masa de un kilogramo. La unidad de presión o esfuerzo es el pascal (Pa) y equivale a la noción abolida de kilogramos (fuerza) por centímetro cuadrado: 9 806 650 kg (fuerza)/m^2 = 1 Pa.

Reglas principales para la consignación de las unidades SI

1. No se usan las mayúsculas en los nombres de unidades. Unica excepción: grados Celsius.

2. Los simbolos no se escriben con mayusculas. Excepciones: los derivados de nombres de personas.

3. Los prefijos métricos no se escriben con mayúsculas. Excepciones: tera T, giga G, mega M.

4. Los simbolos se escriben siempre igual, sean singular o plural, ej.: 5 mm, no 5 mms.

5. Cuando se escriben los nombres de unidades completos, se pluralizan normalmente, ej.: 10 kilogramos, 55 hectáreas.

6. No se usan los prefijos solos, sino acompañados de la unidad, ej.: 15 megawatts, no 15 megas.

7. No se usa el punto después del símbolo (24 m, no 24 m.), excepto al final de un párrafo.

8. Siempre se deja un espacio entre el número y el simbolo o unidad, ej.: 10 cm, no 10cm

9. No se usan comas ni puntos para separar números largos; se deben separar de tres en tres. El punto marca el principio de la fracción decimal, ej.: 1 000 005.34, 30 000 y no 1,000,005.34 ó 30,000.

10. Siempre se coloca un cero a la izquierda del punto decimal, ej.: 0.77 y no .77.

11. Cuando se expresan unidades compuestas como kilómetros por hora, se usa la diagonal, ej.: 78 km/h, 50 m/s. Si se trata de newton metros se usa el punto, ej.: 5 N.m.

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